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Geology of the Saddle Pond – Grand Lake Seboeis Region, North-Central Maine Part 1: 1991 Field Update

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INTRODUCTION

Systematic geologic mapping of the Saddle Pond-Grand Lake Seboeis region, north-central Maine, at a scale of 1:24,000 was initiated during the summer of 1990 and was resumed for six weeks in 1991. Most of the mapped area lies within portions of the Millinocket Lake East, Frost Pond, Trout Brook Mountain, and Grand Lake Seboeis 7.5' quadrangles; minor work was undertaken in the Millinocket Lake West, Hay Lake, and LaPomkeag 7.5' quadrangles. A companion mapping project is being undertaken in the southern portion of the Millinocket Lake West quadrangle by Mr. Stephen Hall (North Carolina State University graduate student); this area is described in Part 2 of this report. The main access to the region is via Huber Co. logging roads and local skidder trails.

A systematic geologic survey of the region has never been undertaken, although reconnaissance visits to the area were made by Drs. R. Neuman, D. Rankin, and B. Hall during the 1960's and 1970's. Neuman (1967) carried out systematic geologic mapping in the Shin Pond and Staceyville 15' quadrangles, immediately to the southeast of the present field area. Rankin (1968) undertook studies in the Traveler Mountain area, directly south of Saddle Pond. Hall (1970) mapped the Munsungun anticlinorium, immediately to the northwest of the region studied here. Their brief reconnaissance trips led to the depiction of the geology of the Saddle Pond-Grand Lake Seboeis area as a pair of east-west trending anticlinal structures exposing unseparated Cambrian-Ordovician rocks on the recent geologic map of Maine (Osberg et al., 1985) (Fig. 1). Major results of the present study include (1) the geology of the area is more varied and complex than that of simple anticlinoria, (2) most of the rocks in the area are likely of Siluro-Devonian age, and (3) the area has been affected by two stages of Acadian deformation, the first phase never before recognized and involving convergent strike-slip tectonics.

The following report supersedes the 1990 field report. It incorporates large segments of the 1990 field report, updates the

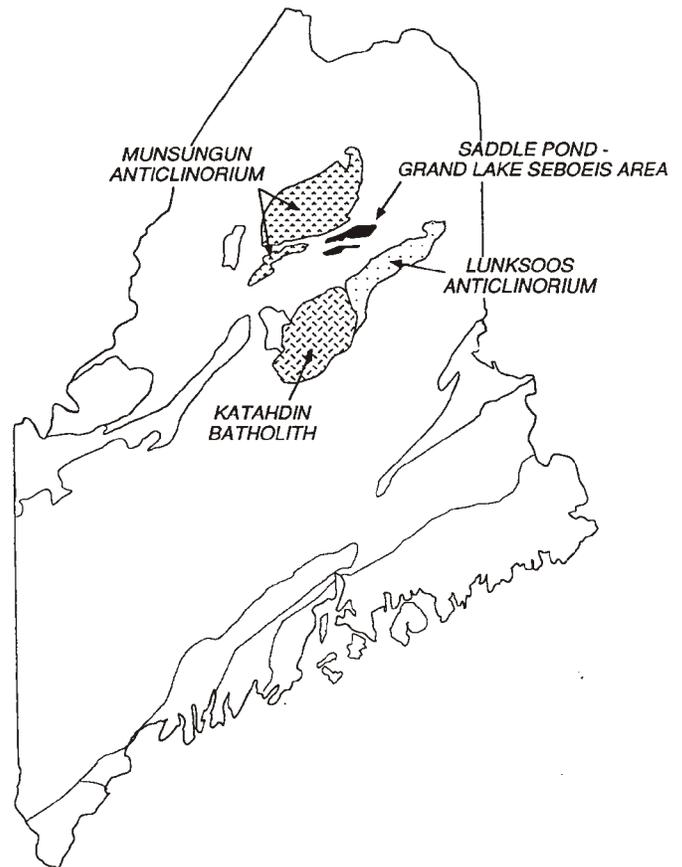


Figure 1. Regional setting of the Saddle Pond - Grand Lake Seboeis area.

1990 field report with petrographic descriptions, re-examination of some 1990 locales, and newly available paleontology data, and describes new field work carried out in 1991. The revised geologic map is s Plate 1 of this report.

Regional Setting

Rocks of the Saddle Pond area occupied a geologic transition zone during both the Early and Middle Paleozoic. To the northwest, Early Paleozoic rocks of the Munsungun anticlinorium appear to have been deposited upon an ophiolitic basement (Osberg et al., 1985). In contrast, similar age rocks of the Lunksoos anticlinorium to the southeast were unconformably deposited upon a Penobscottian deformed Late Precambrian-Cambrian sedimentary sequence. Along strike to the northeast, in New Brunswick and Newfoundland, these metasedimentary rocks are interpreted as representing the eastern margin of a continental basement terrane. Thus, the Saddle Pond-Grand Lake Seboeis area appears to straddle the zone between contrasting Early Paleozoic basement terranes.

Middle Paleozoic rocks of north-central Maine record a transition from an apparently shallow marine, varied sedimentary-volcanic sequence in the west to a deeper marine, less varied, mainly basinal sedimentary sequence to the east (e.g. Neuman, 1967; Roy, 1980). In the Lunksoos anticlinorium, immediately southeast of the present study area, this transition is abrupt and exhibited by Silurian-Devonian rocks on opposing flanks of that structure. Silurian-Devonian rocks in the Saddle Pond area coincide with the eastern extent of the Middle Paleozoic varied sequence.

Four major informal lithologic divisions of sedimentary and volcanic rocks have been outlined in the Saddle Pond-Grand Lake Seboeis region during the 1990 and 1991 field campaigns: these include the (1) the Saddle Pond formation, an intensely deformed unit of metaclastic rocks, (2) the Ireland Pond assemblage, dominated by mafic volcanic and volcanoclastic rocks, (3) the Grand Lake Seboeis group, containing a varied sequence of slate, conglomerate, and a wide range of volcanic rocks, and (4) the Millimagassett Lake formation, a sequence of alternating, thin- to medium-bedded sandstone and slate. All of the units are imprinted with low grade metamorphism; also, they are intruded by small stocks of both felsite and gabbro, many of which are below map resolution at the scale of 1:24,000. The full distribution of all of the units in the area is yet to be delineated; likewise, the relationship of these units to formations recognized in nearby, previously mapped, areas is speculative at this time.

SADDLE POND FORMATION (O_{sp})

General

The Saddle Pond formation is the informal name given here to the intensely deformed sequence of mainly gray to black phyllite and subordinate quartz-rich graywacke that crops out in

the southwest portion of the field area. The unit is disposed in three east-west trending, subparallel, though interconnected, outcrop belts. The southern belt is interpreted to be separated from the other two belts by an approximately east-west trending fault. The northerly belts merge to the east, although they are likely separated by a high-angle fault. The disposition of the unit will be discussed further in the structural geology section. The thickness of the formation is uncertain due to structural complexity, although its maximum outcrop width is slightly less than 1 km in the area of Saddle Pond. Layering in the unit is steeply to vertically dipping and trends E-W to NW. Rocks typical of the formation are best exposed around the shore of Saddle Pond and in a small road metal quarry at the eastern end of the outcrop belts.

Description

The unit is dominated by white- to cream-weathering gray and black phyllite, locally ankeritic, with lensey inter laminations of light green to gray tuffaceous(?) mudstone; subordinate interlayers of a distinctive gray coarse-grained, quartz-rich graywacke are common in the formation. The tuffaceous mudstone laminae range up to approximately 10 mm thick and are generally discontinuous over a span of 10 mm to 50 cm. In a small borrow pit at the northeast margin of the outcrop belt, layers of punky weathering carbonate (probably dolomite) up to 5 cm thick are interlayered with phyllite. The graywacke is characterized by strikingly coarse glassy quartz grains that in many places have a bluish hue. The graywacke layers are up to 1 m thick and are usually discontinuous, exhibiting boudinage and pinch and swell features. Locally, the graywacke is totally surrounded by the phyllite, suggesting extreme dismemberment of layering. The discontinuous geometries of both the mudstone and graywacke interlayers are attributed to tectonic deformation in the region. At a few localities, the phyllite is pebbly, containing clasts of light gray tuffaceous mudstone, quartz graywacke, quartzite, and altered volcanic rock. In thin section, the sand-sized grains and smaller pebbles are dominantly quartz (both volcanic and metamorphic) plagioclase crystals, black mudstone, and highly altered plagioclase-rich volcanic (basalt?).

Contact Relationships

The Saddle Pond formation is clearly faulted against the Ireland Pond assemblage; sheared phyllite is found in many places at the base of the slope marking this contact. The easterly extent of this fault is uncertain, but it appears to bifurcate to the northwest of Saddle Pond, with a fault-bounded sliver of Grand Lake Seboeis group intervening between the two units. Likewise, other contacts of the northerly Saddle Pond outcrop belts are not exposed, but here are assumed to be tectonic because of the strong deformation in the area and the sliver-like nature of the outcrop belts. The southerly outcrop belt also appears to be

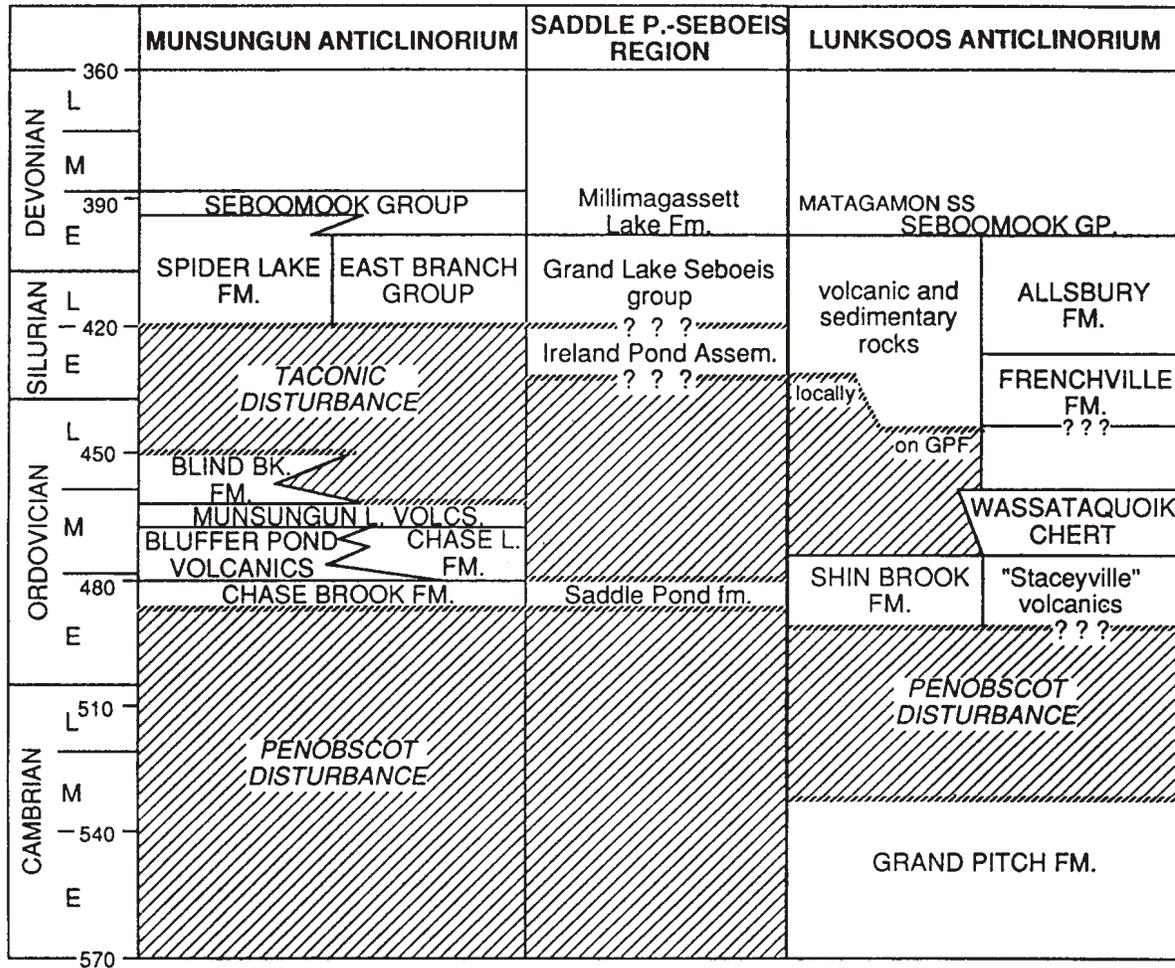


Figure 2. Tentative stratigraphic correlation chart for north-central Maine.

fault-bounded. An intense foliation is observed at many locales along the southern border of the belt and along its eastern extension, and brecciated and veined rock (felsite?) is found along the contact. The northern boundary of the southern belt is interpreted to be faulted on the basis of intensely foliated rocks localized along the contact on the north side of Saddle Brook.

Age and Correlation

There is no direct evidence for the age of the Saddle Brook formation. Lithologically, it is distinct from other units in the Saddle Pond-Grand Lake Seboeis area. However, the formation does resemble rocks in both the Munsungun and Lunksoos anticlinoria. The Saddle Pond formation bears close resemblance to the black phyllite-quartz graywacke-carbonate assemblage of the Chase Brook Formation in the Munsungun anticlinorium (Hall, 1970). In particular, the Saddle Pond formation is lithically indistinguishable from rocks of the Chase Brook Formation exposed at Munsungun Falls, located in the northern portion of the Millinocket Lake West 7.5' quadrangle.

The Chase Brook Formation appears to be of middle to upper Arenig age on the basis of one conodont locality containing the species *Periodon flabellum* (Lindstrom) (reported in Neuman et al., 1989). Thus, the Saddle Pond rocks are here interpreted to be of Early Ordovician age (Fig. 2).

The Saddle Pond formation also bears lithic resemblance to portions of the Grand Pitch Formation in the Lunksoos anticlinorium (Neuman, 1967); in particular it corresponds to the black slaty member that is common along the northwest side of the Grand Pitch outcrop area (Neuman, 1967; Ekren and Frischknecht, 1967; G. Boone, pers. commun., 1990; pers. obsvtn., 1990). The Grand Pitch Formation is considered to be Cambrian in age, on the basis of local occurrences of the trace fossil *Oldhamia smithi* (Neuman, 1967). However, these fossils are found in a red slate-siltstone member of the formation that is of uncertain stratigraphic position relative to the black slate member. It is possible that the black slate member may form a stratigraphic unit distinct from the Grand Pitch Formation (G. Boone, pers. commun., 1991) and the age of the black slate remains uncertain.

IRELAND POND ASSEMBLAGE ($S_{mv, vc, fv, s}$)

General

The belt of rocks dominated by mafic volcanic and volcanoclastic rocks that extends from the Grand Lake Seboeis 15' quadrangle west-southwesterly onto the Traveler Mountain 15' quadrangle is informally assigned to the Ireland Pond assemblage. During the 1991 field season, a second outcrop area of the assemblage was discovered in the Boody Brook-Grand Lake Seboeis area. The Ireland Pond assemblage corresponds to the Ireland Pond belt of the 1990 field report (Hibbard, 1991). Ireland Pond is surrounded by rocks of the assemblage, but underlain by Devonian(?) gabbro and felsite; however, because Ireland Pond is one of the few named geographic features in the belt, it is used here to denote the belt. In addition to mafic volcanic rocks, the belt contains epiclastic and clastic rocks and subordinate felsic volcanic rocks; varicolored slate on the northwest side of Grand Lake Seboeis is herein included in the assemblage. Also, a few outcrops of granitoid rock, too small to be resolved at map scale, have been found in the felsic volcanic rocks. The thickness of the unit is uncertain because of structural complexity; the maximum outcrop width is approximately 2.7 km in the area of West Branch Sawtelle Brook. The attitude of layering in the belt is highly variable, although the average trend is east-northeast.

Description

Mafic Volcanic and Volcanoclastic Rocks (S_{mv}, S_{vc}): Mafic volcanic rocks are concentrated mainly in the northeastern and central portions of the main outcrop belt, where pillow basalt and pyroclastics are the dominant rock type. In most outcrops, only portions of pillows are observed; however, where whole pillows are seen, they range from 0.3 to 1.5 m in diameter. Locally the lavas are feldspar-phyric and amygdaloidal. Inter-pillow material is generally a gray-green chert, although burgundy chert was observed at one locale. Pillow breccia commonly associated with the lavas contains clasts up to 20 cm across. In many places, dikes(?) and small stocks of diabase and medium-grained gabbro are associated with the mafic volcanic rocks. In the Boody Brook area, almost all of the rocks noted to date are pillow lava, pillow breccia, or associated lapilli tuff. In this area, dark gray to dark green chert commonly forms inter-pillow material.

In thin section, the pillow lavas are commonly altered and display a subophitic to trachytic texture. The most common constituents are plagioclase, chlorite, clinopyroxene (augite?), and epidote, set in a brown-gray to isotropic cryptocrystalline groundmass. Locally the volcanic rocks are amygdaloidal with calcite and epidote fillings. The plagioclase forms both a felted groundmass of microlites and phenocrysts that average ~0.5 mm

long but range up to 5.0 mm long; locally the plagioclase is glomerophenocrystic. Almost all of the plagioclase is highly altered to a turbid mixture of fine-grained carbonate and sericite.

The most common mafic volcanoclastic rock is a dark green chloritic phyllite that locally exhibits mm-scale layering. Layers in the phyllite appear to be defined by varying concentrations of chlorite, epidote, actinolite, muscovite, feldspar quartz. Mafic lapilli tuff and agglomerate are common along the ridge just south of Little Beaver Pond. One mafic breccia in this area contains fist-sized clasts of brick red chert. In places, medium-grained feldspar-quartz mafic sandstone with a dark green chloritic matrix is interlayered with the phyllite. Where found, the sandstone is generally medium-bedded. One section of mafic sandstone in the hills just south of Little Beaver Pond contains interlayers up to 1 m thick of greenish-black chert to siliceous mudstone. Purple and reddish-purple phyllite and slate were observed in the area between the two branches of Sawtelle Brook.

Volcanic conglomerate is a conspicuous, although rare, component of the belt. Generally, the volcanic conglomerates are matrix-supported with purple to burgundy slate and chloritic phyllite forming the matrix. Clasts in the conglomerates range up to large cobbles and include, in order of abundance, amygdaloidal mafic volcanic rock, locally with chilled selvages, mafic epiclastic rocks, red slate, jasper, gray chert, pyroxene-tuff, and limestone. A distinct volcanic conglomerate composed of mafic volcanic cobbles in a red quartz-feldspar sandstone to mudstone was found in the hills just southwest of the source of Hay Brook.

An unusual mafic volcanoclastic rock occurs in many places in the belt, although it is most common in the area west of Hay Brook. It is composed of angular layered clasts of chlorite-epidote-feldspar mafic volcanoclastic rock with individual clasts defined mainly on the basis of the orientations of layering in the clasts differing from that of neighboring clasts. Matrix is very scant, if present at all, and appears to be of the same composition as the clasts. Locally, the clasts are composed of a coarse-grained pyroxene tuff. A layer-parallel foliation is developed in the clasts. This rock may represent an autobrecciated mafic tuff or epiclastic rock.

Felsic Volcanoclastic Rocks (S_{fv}) form a discontinuous belt along the north-northwest side of the assemblage. Most commonly they are bleach-white weathering, light greenish gray to dark green-black dacitic(?) lapilli tuffs and quartz-feldspar crystal tuffs. Locally, dacitic volcanic conglomerates containing pebbles to cobbles of dacite, jasper, and dark gray slate are associated with the tuffs.

In thin section, the felsic volcanic rocks have a fine-grained plagioclase-quartz-sericite matrix that surrounds either plagioclase and quartz crystals or lithic fragments of crystal tuff. In addition, chlorite, carbonate, apatite, and zircon are found in the groundmass.

A small body of medium-grained equigranular feldspar-quartz-chlorite granitoid rock is closely associated with the felsic volcanic rocks in the group of hills just to the north of Bea-

ver Brook. It is too small to be resolved at a 1:62,500. The felsic volcanic rocks appear to structurally drape over the granitoid body, although the relationship between the two units is not exposed. The granitoid is mainly massive with only a local weak foliation and is cross-cut by numerous quartz veins.

Varicolored slate (S_v) forms a large outcrop area between Jones Pond, Boody Pond, and Grand Lake Seboeis. Although distinct from other rock types in the assemblage, the slate is here included in the unit because (1) the slate unit displays a similar structural history as the rest of the assemblage and (2) the slate appears to be along strike with the Boody Brook area volcanic rocks, although the relationship between these units is unexposed. The slate includes purple, burgundy, red, black, gray, gray-brown, gray-green, and pale green slate with only minor coarser clastic interlayers. In places, the colors alternate irregularly, and do not appear to connote bedding. Along the northwest shore of Grand Lake Seboeis, gray-brown slate contains thin laminae (mm scale) of siltstone and tuffaceous siltstone. Also along this coast, a single fine-grained, 30-cm thick, gray sandstone bed is interlayered with otherwise monotonous gray slate.

Contact Relationships

The contact of the Ireland Pond assemblage with the Saddle Pond formation is a fault, as discussed above. The contact of the belt with the Grand Lake Seboeis group has not been observed, but is thought to be either unconformable or tectonic and will be discussed following a description of the Grand Lake Seboeis group.

Age and Correlation

There is no direct evidence for the age of the Ireland Pond assemblage. In 1990, two micritic limestone clasts from volcanic conglomerates of the assemblage were sampled for potential conodont analysis. Dr. Svend Stouge of the Danish Geological Survey, Copenhagen, Denmark, has reported the clasts to be barren of microfossils. On the basis of rough lithic similarity with portions of the structurally (and possibly stratigraphically) overlying fossiliferous Late Silurian-Early Devonian Grand Lake Seboeis group (see below), the Ireland Pond assemblage is tentatively considered to be Silurian in age, although an older, possibly Ordovician age cannot be ruled out.

GRAND LAKE SEBOEIS GROUP ($SD_{c,cs,vc,s,ls,ss}$)

General

The Grand Lake Seboeis group is a heterogeneous assemblage of slate, clastic sedimentary rocks, and mafic and dacitic volcanic and associated rocks. The group forms two west-south-

west-trending belts that flank the main outcrop belt of the Ireland Pond assemblage. The southerly belt is structurally dissected by apparently fault-bounded slivers of the Saddle Pond formation, near Saddle Pond. The group is named for the slate and clastic sedimentary and volcanic rocks that crop out around the shores of Grand Lake Seboeis. The true thickness of the unit cannot be accurately estimated due to the combined effects of complex facies changes and complicated structure in the belt. The maximum outcrop width of the unit is greater than 5 km in the area just west of Grand Lake Seboeis where the two outcrop belts appear to merge. The attitude of bedding in the unit is variable.

The complex and abrupt facies changes within the unit, combined with complicated structure precludes the determination of an internal stratigraphy for the group. However, it appears that conglomerate and clastic sedimentary rocks tend to outcrop near apparently older units in the area and are interpreted as representing basal portions of the group; in contrast, the slaty rocks and a distinct sandstone unit, the Scraggly Lake sandstone, are found adjacent to the younger Millimagassett Lake formation and are here considered to represent the upper stratigraphic portions of the group.

Description

Mixed Clastic Sedimentary Rocks (SD_{cs}) and Conglomerate (SD_j): South-southwest of Scraggly Lake, the belt consists of a varied assemblage of clastic sedimentary rocks, including a variety of colors of slate (red, gray, purple, burgundy), calcareous slate and sandstone, conglomeratic slate, varicolored phyllite, blue-green mudstone, varicolored mudstone, pebbly mudstone, iron formation, red sandstone, green-gray sandstone, mafic volcanoclastic sandstone, red conglomerate, and blue-green conglomerate. These rock types are disposed in a seemingly random mosaic in which individual rock types can not be traced along strike for any significant distance and abrupt lateral facies changes are common. Mudstone and conglomerate appear to be the most abundant constituents of this member.

Coarse conglomerate (SD_c) forms the most conspicuous member of this assemblage and can be found throughout the belt either mixed with other clastic sedimentary rocks or as isolated mappable units. It is generally massive, clast-supported with a matrix of either red or blue-green sandstone-mudstone; bedding is rarely evident. Clasts vary from angular to well-rounded and range in size from granules up to large boulders, >1 m in diameter. Clast composition is varied and, in order of abundance, includes mafic to dacitic volcanic rocks (fine-grained and porphyritic), epiclastic rocks, vein quartz, mudstones of various colors (gray, red, purple, green, aquamarine), red slate, jasper, red sandstone, gray chert, limestone (locally fossiliferous), blue-green and bronze phyllite chips, fine- to medium-grained granitoid rocks, diabase, quartz-wacke, ironstone, black phyllite, quartzite, reddish quartz porphyry, and crenulated biotite(?) schist. In the area on the northwest side of Grand Lake the

conglomerate contains abundant conspicuous pebble- to boulder-sized red feldspar-phyric and flow-banded rhyolite clasts that are not commonly seen in other areas. In most outcrops of the conglomerate there are clasts with a pre-incorporation tectonite fabric. The most common "pre-deformed" clasts include mudstone, slate, phyllite (locally crenulated), ironstone, and epiclastic rocks.

A striking sequence of varicolored sedimentary rocks is exposed along the logging road that lies just to the west of Hay Brook, to the northwest of Saddle Pond. The sedimentary rocks here include interbedded red slate, conglomerate and gritty sandstone, blue-green sandstone, red mudstone, iron formation, gray sandstone, fossiliferous burgundy and blue green mudstone, and both red and blue green conglomerate. The conglomerates are massive, forming units up to 10 m thick; the sandstones and mudstones are generally medium-bedded and alternate regularly. Locally, the mudstones form massive sections up to 10 m thick. The effects of regional tectonism and complex facies distribution preclude any simple deduction of the local stratigraphy in this well-exposed section.

One section of red, purple, light green, and gray phyllite was noted along the Huber Road, approximately 1.5 km southwest of Scraggly Lake. On a nearby logging road to the southeast of the phyllite, a distinct phyllite-chip conglomerate is interbedded with slate and conglomeratic slate. The relationship between the varicolored phyllite and the phyllite-chip conglomerate is uncertain at this time.

The remainder of the mixed clastic rock member consists of drab buff to white-weathering gray slate, siltstone, and sandstone that are generally nondescript relative to those rocks described above.

Mixed Volcanic and Clastic Sedimentary Rocks (SD_w):

The Grand Lake Seboeis group contains a mixture of volcanic and volcanoclastic rocks in addition to the clastic rocks described above in the area of Saddle Pond, Grand Lake Seboeis, and locally on Millimagassett Lake. The volcanic rocks range in composition from basalt to dacite; basalt appears to be prevalent in the Saddle Pond area and on Millimagassett Lake, whereas dacite appears to dominate the assemblage in the area of Grand Lake Seboeis. Locally, on the west side of Grand Lake Seboeis, pink rhyolite forms a part of this member.

The basalts are generally massive and range from dark green to purple in color. Purple weathering pillow lavas with pillows <1 m in diameter were noted along the southwest shore of Saddle Pond and in the inland area just west of Grand Lake Seboeis. In the Saddle Pond area, these rocks are intensely foliated and altered, although locally pillow forms and chilled margins are well preserved. The interpillow material here includes bright red chert and pinkish carbonate. Purple to blue-green aa-like lavas were noted on the northwest shore of Millimagassett Lake. In thin section, one of the basalts from the thin outcrop strip north of Saddle Pond displays an ophitic to subophitic texture with approximately 45% plagioclase, 30%

clinopyroxene (augite?), 10% chlorite, 5% epidote and the remainder of opaques and dark, irresolvable groundmass.

Mafic fragmental rocks generally contain angular, amygdaloidal dark green and purple clasts <25 cm in diameter. One outcrop of a mafic fragmental rock similar to the unusual mafic breccia found in the Ireland Pond assemblage was observed in one of the fault-bounded slivers of the Grand Lake Seboeis group, north of Saddle Pond. In places, the basaltic rocks appear to be heterogeneously altered to a more silicic composition at the outcrop scale.

The dacites of this member commonly range in color from lavender-gray and oxidized red-purple to light gray-green and yellow-green. They are most common in the area to the east and southeast of Saddle Pond and along the shores of Grand Lake Seboeis. In most places, the dacites are fragmental, although pillowed and massive varieties have been noted in the area. Dacitic to intermediate pillow breccia and generally poorly developed pillows are found on the small islands and shoreline at the southern end of The Narrows of Grand Lake Seboeis. Individual pillows here range up to ~0.8 m across and display good chilled selvages. Massive dacitic rocks are found locally in the inland area west of Grand Lake Seboeis and in the hilly area to the west of Saddle Pond. At the latter locale, the dacites are a yellow gray-green in color, roughly cleaved, and contain quartz eyes. Massive, weathered dacite with spherules up to 5 mm in diameter was found in the hills just west of southern Grand Lake Seboeis.

In thin section, the dacites consist of dominantly plagioclase microlites set in an optically irresolvable dark groundmass, with chlorite, biotite, epidote and abundant secondary calcite. Texturally they range from pilotaxitic to hyalopilitic.

Rhyolitic rocks outcrop locally along southwestern Grand Lake Seboeis and along the access road to the lake. Outcrops in the road are pinkish-red and flow-banded. Those along the lake shore are pink, massive, and aphanitic with quartz and feldspar phenocrysts. Here, zones of brecciated (cm-scale) rhyolite traverse the outcrops and appear to define a primary layering.

All of the volcanic rocks of this member are closely associated with the sedimentary rocks of the group. The aa-like lava on Millimagassett Lake is intimately associated with red clastic sedimentary rocks, especially red conglomerate, and calcareous slate. Locally, the chaotic intermingling of lava and conglomerate relationships suggest a laharic origin for the resultant hybrid rock. A layer of intensely foliated blue-gray micritic limestone ~2 m thick is interlayered with dacitic and mafic volcanic rocks in the area just to the southwest of Saddle Brook. Also in this area, the volcanic rocks are commonly interleaved with a purple mudstone matrix volcanic conglomerate and dark green graywacke. On the east shore of The Narrows of Grand Lake Seboeis, massive and fragmental gray dacite is interlayered with arkosic graywacke, siliceous mudstone, and crystal tuff, forming a conformable sequence approximately 20 m thick. Just to the

west of the lake, the dacites appear to be interlayered with gray slate and red conglomerate.

The outcrop “tongue” of the group that is sandwiched by the Saddle Pond formation just to the north of Saddle Pond is comprised mainly of epiclastic rocks and phyllite, with subordinate purplish-green and green mafic volcanic and pyroclastic rocks. The epiclastic rocks are mainly thick- to medium-bedded white-weathering chloritic green to blue mafic sandstones and mudstones with medium-bedded aquamarine siliceous mudstones, gray-green, brown, purple-gray and light green phyllite, and minor volcanic conglomerate. At one locale, a 25-cm thick bed of burgundy chert is interlayered with dark green quartz-bearing volcanic sandstone and laminated aquamarine siliceous mudstone. A distinct red sandstone-mudstone mafic volcanic conglomerate, similar to that found in the Ireland Pond assemblage, is found at the east end of the outcrop tongue. A 25-cm thick whitish gray bioclastic limestone bed is either interlayered with or forms a large boulder in the conglomerate. Most of the fossil debris in this layer is pelmatozoan hash with some bryozoan and coral fragments.

Slate (SD₁): Cream- to bleach white-weathering dark gray to green-gray slate comprises a large proportion of the Grand Lake Seboeis group to the north and west of Scraggly Lake, along the northern side of the Ireland Pond assemblage between Little Beaver Pond and the East Branch of the Penobscot, and in the area between Sawtelle Brook and Snowshoe Lake. The slate is remarkably featureless, only locally exhibiting thin, <10 mm thick siltstone and fine-grained sandstone beds. It appears that most of the slate is slightly calcareous and locally detrital(?) muscovite is evident. In all areas, the slate appears to be near the top of the group, adjacent to the overlying Millimagassett Lake formation.

Calcareous Slate (SD_{1b}): Gray to light blue-gray calcareous slate forms a major portion of the group on the north side of Millimagassett Lake and has been traced as far east as Sawtelle Brook. It also forms smaller outcrop areas, spatially associated with the volcanic rocks around the southern end of Grand Lake Seboeis. The calcareous slate is very similar to the slate described above except that it has a higher carbonate content and commonly is highly fossiliferous. In many places the carbonate forms isolated light blue-gray pods and irregular beds that readily weather out, giving the rock a distinct pitted aspect; this led R. Neuman to term the rock “pit rock” during his reconnaissance of the area. Locally, such as on the prominent peninsula at the south end of The Narrows of Grand Lake Seboeis, some beds are bioclastic, composed almost entirely of fossils.

At Millimagassett Lake, the calcareous slate has a red slate member near the top of the unit. On the north shore of the lake, calcareous red mudstone-siltstone is interlayered with green-gray siltstone, whereas at the east end of the lake, this upper unit is characterized by a deep red calcareous slate. To date, this “red member” has been traced discontinuously eastward to the Sawtelle Pond area. Also near the top of the calcareous slate,

a few frosty gray, fine-grained sandstone layers up to 25 cm thick are intercalated with the slate.

Scraggly Lake Sandstone (SD_{2s}): A distinct, fine- to medium-grained, frosty blue-gray sandstone member that appears to be confined to the central and eastern portions of Scraggly Lake is here termed the Scraggly Lake sandstone. The sandstone commonly forms massive beds up to 2 m thick that are internally graded, cross-bedded, and locally display convolute bedding, slump folds, and load casts. Locally, beds of slate up to 15 cm thick intervene between the massive sandstone ledges. On the north shore of Scraggly Lake, in the lagoon-like portion of the lake termed the Back Room, the sandstone appears to grade stratigraphically down into massive siltstone. Neuman (1967) has reported intraformational conglomerate from this area. The Scraggly Lake sandstone appears to overlie the slate member of the Grand Lake Seboeis group to the north and west of Scraggly Lake.

Contact Relationships

The contacts of the Grand Lake Seboeis group with both the Saddle Pond formation and the Ireland Pond assemblage are unexposed. In the area north of Saddle Pond, the Grand Lake Seboeis group and Saddle Pond formation are apparently interleaved along tectonic contacts. In most places, rocks of both units are intensely foliated near the contact or the trend of Grand Lake Seboeis strata is at a very high angle to that of the nearby Saddle Pond formation strata.

The contact between the Grand Lake Seboeis group and the Ireland Pond assemblage is abrupt with respect to both stratigraphy and structure. Locally, it appears that the trend of layering in the Ireland Pond assemblage is at a high angle to that of the Grand Lake Seboeis group, for example in the area north of Scraggly Lake. These observations suggest that the contact of the group with the assemblage is tectonic. However, it is troublesome that near their contact the two belts locally appear to have overlapping facies. In particular, outcrops of the coarse red and blue-green conglomerates of the Grand Lake Seboeis group are surrounded by Ireland Pond rocks near the contacts of the two units. The units also share in common the unusual mafic breccia “autobreccia” described above, and distinct red matrix mafic volcanic conglomerates. The distribution of these facies near the contact of the units suggests that either the units were originally unconformable with the erosional surface approximately at the present surface of the Ireland Pond rocks or it is possible that the belts originally interfingered conformably and are largely time equivalents. At the present time, the interpretation that the Grand Lake Seboeis group unconformably overlies the Ireland Pond assemblage is favored on the basis of apparently discordant structural relations near their mutual contact and the outlier-like character of Grand Lake Seboeis rocks near the margins of the Ireland Pond outcrop belt.

Age and Correlation

Numerous macrofossil localities have been found in the Grand Lake Seboeis group during the present study as well as during reconnaissance by D. Rankin during the 1960's. In addition, one microfossil locality was discovered during this study. For both the present study and for Rankin's work, macrofossil identification has been undertaken by Dr. A. Boucot (brachiopods), Dr. W. Oliver (corals), and Dr. R. Neuman (brachiopods). Conodonts have been extracted from rocks of the group and identified by Dr. S. Stouge. The details of the paleontological data is presented in the Appendix to this report.

The tightest constraints come from calcareous slate near Soule Pond, a volcanic conglomerate northeast of Saddle Pond, siltstone just north of Scraggly Lake, and two localities south of Saddle Pond. The slate near Soule Pond appears to be near the top of the group in this area and yields a Pridolian fauna. The sample from a bioclastic limestone lens or clast in the volcanic conglomerate near Saddle Pond indicates a probable Heldebergian (Gedinnian) age. Unfortunately, this portion of the group is in a fault-bounded sliver, and its stratigraphic position in the group is ambiguous. The siltstone locality north of Scraggly Lake was reported by Neuman (1967) and appears to be lower Ludlovian. The samples south of Saddle Pond were collected by Rankin and indicate a lower Ludlovian age (D. Rankin, pers. commun. 1991, quoting A. Boucot). Other locales give more ambiguous age constraints that range from upper Llandovery to Early Devonian. Thus, fossils from the group appear to indicate an age range from Ludlovian to Gedinnian, with the possibility that older, Llandovery rocks may be present in the group.

The Grand Lake Seboeis group is similar to Late Silurian-Early Devonian rocks in the surrounding region. In particular, the belt is very similar to descriptions given by Hall (1970) for the East Branch Group in the Munsungun anticlinorium. The belt is also lithically similar to and partially overlaps with unnamed Silurian-Devonian rocks described by Neuman (1967) from the northwest side of the Lunksoos anticlinorium. Silurian-Devonian units from these three areas are herein considered to be correlative (Fig. 2).

MILLIMAGASSETT LAKE FORMATION (D_{ml})

Description

A distinct unit of very regularly graded beds of buff weathering fine-grained sandstone and medium gray to gray brown slate forms outcrops along the south shore of Millimagassett Lake and is also found on the south side of Scraggly Lake and near the East Branch of the Penobscot River. The unit is informally termed here the Millimagassett Lake formation for the characteristic exposures on Millimagassett Lake. On the east side of the lake, the formation is estimated to be about 600 m thick. Typically, the beds of the unit range from 5 to 10 cm thick.

Locally, medium to thick beds of sandstone up to 30 cm thick interrupt the regular sequence of thin- to medium-bedded sandstone/slate. Likewise, in other locales, slate forms a dominant portion of the section for a few meters. The sandstone beds are commonly graded, exhibit cross-bedding, and locally display sole marks. In the area just to the southwest of Sawtelle Pond, a gray calcareous slate conglomerate is interbedded with typical beds of the formation. Clasts in the conglomerate include corals, limestone, fine-grained clastic sedimentary rocks, pyroxene phenocrystic intermediate volcanic rocks, vein quartz, quartzite, and green phyllite. The beds face north in a section that to the north, is south facing. Its stratigraphic position in the formation is ambiguous, although fossil data suggest that it may be low in the unit (see below).

Contact Relationships

The Millimagassett Lake formation appears to be conformable with the Grand Lake Seboeis group. The formation is faulted against the Ireland Pond assemblage. The contact between the Millimagassett Lake formation and the Grand Lake Seboeis group appears to be gradational over a series of discontinuous outcrops along the western shore of Millimagassett Lake. Here, a few sandstone beds are found near the top of the varicolored slates that compose the calcareous slate member of the Grand Lake Seboeis group, just to the north of the first outcrop of typical Millimagassett Lake formation. Significantly, there is no change in the orientation of bedding between the group and the formation. These observations lead to the interpretation that the contact between the units is conformable here.

Age and Correlation

One macrofossil locale was found in the slaty conglomerate of the formation near Sawtelle Pond. The fauna is listed in the Appendix of this report and loosely indicates an Upper Silurian - Gedinnian age (A. Boucot, pers. commun., 1992). The formation is lithically identical to strata of the Gedinnian - Siegenian Seboomook Group (Pollock, 1987) that is common throughout northern Maine. It is here considered that the Millimagassett Lake formation is a subdivision of the Seboomook Group (Fig. 2). Considering the age constraints for the formation and the Grand Lake Seboeis group, it appears that the Millimagassett Lake formation may laterally interfinger as well as overlie the group.

INTRUSIVE ROCKS (D_{f,g})

Two distinct types of intrusive rock, gabbro/diorite and felsite, form small mappable stocks, dikes, and sills throughout the area. In addition, a small stock of granitoid, unresolvable at the present map scale, is found in the Ireland Pond assemblage (see above). The gabbro is medium-grained dark mottled cream and green color and composed dominantly of chloritized

pyroxene and light green plagioclase. In places the gabbro grades into diorite and quartz diorite and locally the gabbro is associated with diabase. The gabbro is most conspicuous in the area of Ireland Pond, where there are two stocks and at Scraggly Lake, where at least three sills intrude the Scraggly Lake sandstone. These sills at Scraggly Lake are informally assigned to the Owls Head gabbro, for exposures at Owls Head on the east side of the lake. There are also smaller bodies encountered throughout the Ireland Pond assemblage and in the Grand Lake Seboeis group.

In thin section the gabbro/diorite is medium- to coarse-grained and appears to be altered to varying degrees; it is generally composed of plagioclase, clinopyroxene, chlorite, epidote, sericite, zoisite, sphene, \pm quartz. One sample taken from a small stock in the Ireland Pond assemblage just to the north of Mitchell Pond contains primary amphibole that appears to be pargasite.

It is uncertain if the gabbro bodies in the area represent a single intrusive suite or if they form parts of different suites of different ages. The Owls Head gabbro intrudes the Ludlovian or younger Scraggly Lake sandstone. Neuman (1967) reports that gabbro intrudes rocks here assigned to the Early Devonian(?) Millimagassett Lake formation. Thus, at least some of the gabbro bodies in the area are considered here to be Early Devonian or younger in age. Other bodies, such as those in the Ireland Pond assemblage may be older, and genetically related to the mafic volcanic rocks in that unit.

Three varieties of felsic intrusive rocks are found in the area and all are aphanitic to fine-grained. The most common is an aphanitic light gray-green to yellowish gray-green quartz \pm feldspar phenocrystic dacitic rock that is commonly brecciated with fragments <10 cm across. This intrusive rock is mainly found underlying hills in the area just to the northwest of Saddle Pond and intrudes the Ireland Pond assemblage and the Saddle Pond formation. Here, the felsite forms small stocks and appears to hornfels the host rocks locally. Locally in the Saddle Pond formation immediately to the east-northeast of Saddle Pond, pillow forms are found in the center of the mapped body. These pillow forms are reminiscent of pillowed dacite-intermediate volcanic rocks in the Grand Lake Seboeis group in The Narrows.

A second type of felsite is found in the same area; it is a buff-weathering, fine-grained gray felsite with a visible matted texture of plagioclase microlites. This rock generally forms well defined dikes that range up to 3 m across and intrudes the Saddle Pond formation. The same rock type has been observed in the Grand Lake Seboeis group in the area east of Saddle Pond and on the west shore of Grand Lake Seboeis, where it is brecciated.

The third type of felsite crops out only in the area of Ireland Pond. It is a pink-weathering gray aphanitic rock that in all outcrops is fractured and strongly foliated. Its relationship to nearby gabbro and Ireland Pond belt rocks is uncertain.

In thin section, the felsites are similar; typically they are altered and contain plagioclase, quartz, chlorite, epidote, sericite,

and carbonate. In a sample from the Cunningham Mountains, biotite replaced largely by chlorite was noted.

The interrelationships between the felsitic intrusions of the area are unknown. The close spatial relationship between the first two types suggests that they are interrelated. The third felsite is spatially confined to the area of intense gabbro intrusion and these plutonic rocks may be genetically related. The age of the felsic intrusions is uncertain, although it appears that they intrude all of the rocks in the area. Neuman (1967) reported a felsite that intrudes rocks here assigned to the Millimagassett Lake formation on the south side of Scraggly Lake. These relationships suggest an Early Devonian or younger age for the felsites.

The felsite intrusions may be hypabyssal correlatives of the Traveler rhyolite, a large mass of rhyolite approximately 10 km south of Saddle Pond, as first suggested by Neuman and Rankin (1980). The Traveler rhyolite overlies the Siegenian Matagamon Formation and is unconformably overlain by the late Early Devonian - earliest Middle Devonian Trout Valley Formation. Such a correlation suggests an Emsian age for the felsites.

STRUCTURAL GEOLOGY

The structural history of the Saddle Pond-Grand Lake Seboeis area is complex and heterogeneous. It involved the development of penetrative and non-penetrative foliations and associated folds in all rocks as well as faulting during at least two, and probably three, deformational events. On the basis of overprinting relationships, orientation and geometrical character of minor structures, and regional relationships, the following three events are recognized: (1) early phase foliation development, (2) intermediate phase folding, faulting, and foliation development that are interpreted as representing convergent strike-slip tectonics and (3) late phase shortening involving folding, foliation generation, and probably faulting. The early phase event may represent Ordovician orogenesis, whereas the later two events are here considered to be Acadian. The timing constraints and regional considerations will be discussed following a description of each of the deformation phases. It is emphasized here, that the extent and intensity of development of each of the deformational phases varies from unit to unit: the early phase appears to only affect the Saddle Pond formation, whereas the later events affect all strata in the region (Fig. 3).

Early Phase

Foliation: The earliest tectonite fabric observed in the area is a penetrative layer parallel foliation that is pervasive in the Saddle Pond formation. To date, no associated folds have been recognized with this foliation. The fabric is similar to intermediate phase foliations discussed below and may be related to them; however, on the basis of regional relationships, it is thought that

		MILLIMAGASSETT LAKE FM.	GRAND LAKE SEBOEIS GP.	IRELAND P. ASSEMBLAGE	SADDLE P. FM.
SILURIAN / DEVONIAN	Late Acadian	penetrative cleavage and folding	penetrative cleavage and folding	crenulation cleavage and folding	crenulation cleavage and folding
	Early Acadian	map-scale folds and left lateral faulting	local minor folds and crenulations	local minor folds and crenulation cleavage	local minor folds and crenulations
			local complex transposed foliation with minor folds	layer parallel penetrative foliation in "weaker" rocks	layer parallel penetrative fabric ↑ ? ↓ ?
ORDOVICIAN ?					

Figure 3. Structural development of the Saddle Pond - Grand Lake Seboeis area.

this cleavage predates the intermediate phase ones, as discussed below in the timing section.

Where observed in thin section, the fabric is a fine continuous cleavage (Powell, 1979) defined mainly by very fine platy minerals (<0.05 mm long), elongate opaque clots, and elongate quartz grains (~0.1 mm long). In silty layers the cleavage is defined by opaque seams that, in the coarsest layers, define a rough type B to C cleavage (Gray, 1978). In addition, noncoaxial type pressure shadows have been observed around some opaque grains and quartz-chlorite beards fringe some quartz grains. The cleavage is commonly associated with quartz veins that trend at a high angle to the cleavage; the veins have been found to predate the cleavage in some samples, whereas in others the veins overprint the cleavage. The sum of the observations strongly suggests a dominantly pressure solution origin for this foliation.

Intermediate Phase

The intermediate phase of deformation is characterized by local cleavage generation, folding, and faulting. This phase is much more heterogeneously developed than the other phases.

Foliation: At hand-specimen scale a penetrative, generally layer-parallel, cleavage is locally found in the Grand Lake Seboeis group and in weaker rocks of the Ireland Pond assemblage. In places in both units, there appears to be multiple folia-

tion generation during what is considered here as "intermediate phase" (i.e. the fabric is thought to postdate the early foliation but predate the late deformation). In the Grand Lake Seboeis group, the cleavage is best exposed in the fault-bounded outcrop sliver just north of Saddle Pond, where it trends approximately east-west. Thin section inspection of this rock indicates that the penetrative fabric is a discrete crenulation cleavage (Gray, 1977) that affects an earlier, layer subparallel continuous cleavage and is axial planar to small, cm-scale rootless folds in siltstone laminae. Both of these cleavages are affected by two later crenulation sets, one apparently of the intermediate phase and the other related to the late phase event. The location of this sample near the boundary of a fault-bounded sliver suggests that the intermediate phase cleavages may be the result of cyclic transposition in a shear environment (Mawer and Williams, 1991).

In the Ireland Pond assemblage, the main penetrative foliation is a layer-parallel penetrative cleavage that is more widespread than in the Grand Lake Seboeis group, but is confined to volcanoclastic rocks and slate. To date, no folds have been found associated with this fabric. In the one thin section in which this fabric has been observed, it is a fine continuous cleavage. This particular sample is affected by two later crenulation cleavages, one apparently an intermediate phase zonal crenulation cleavage that trends westerly and the other a late zonal crenulation cleav-

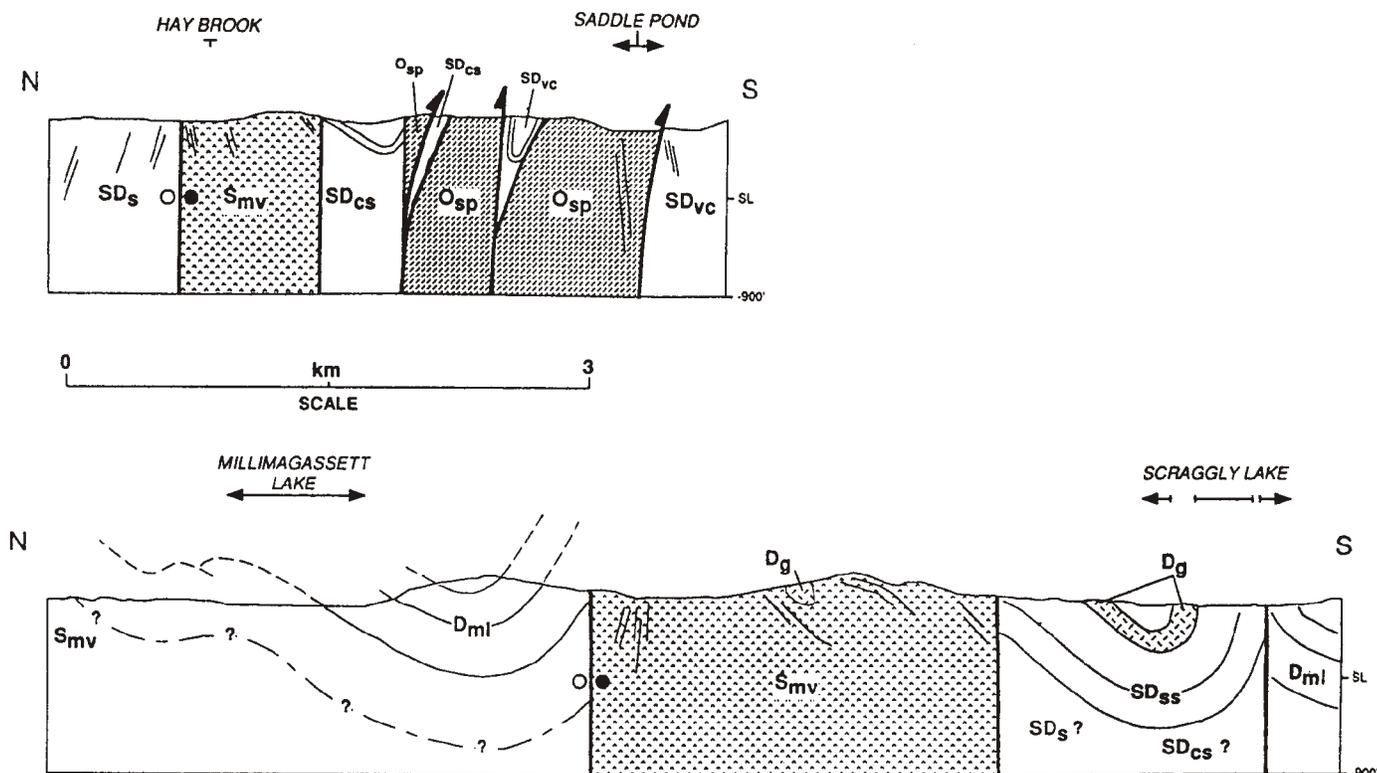


Figure 4. Interpretive cross-sections through the Saddle Pond fault system (top) and intermediate phase folds on Millimagassett and Scraggly Lakes (bottom).

age that conforms in orientation to the typical late phase cleavage (see below). The origin of the penetrative fabric and intermediary crenulation is uncertain, but again, the complex foliation history suggests that cyclic transposition may be responsible for multiple intermediate phase foliation generation, at least locally, in the assemblage.

Folds: Map-scale folds of the intermediate phase are best documented by first-order synclines in the Millimagassett Lake formation and Grand Lake Seboeis group in the areas of Millimagassett Lake and Scraggly Lake. The folds are generally asymmetric, upright, and subhorizontal (Figs. 4, 5, 6, 7, 8). They plunge gently in either an easterly or westerly direction and the first order folds have a half-wavelength >2 km; they are characterized by steeply north-dipping southern limbs and gently south-dipping northern limbs (Fig. 4). The folds lack an axial planar fabric, but have been overprinted and transected by the late phase cleavage (described below) (Figs. 6, 7, 8). The departure of these folds from near-cylindricity is likely due to modification of bedding orientation by the late phase deformation (Figs. 5, 6, 7, 8).

Two anticlines in the Grand Lake Seboeis group near the outlet to Millimagassett Lake are here interpreted to be second order parasitic folds on the northern limb of the first order syncline that affects strata around the lake (Figs. 4, 7). In contrast to the west-southwest plunge of the first order syncline,

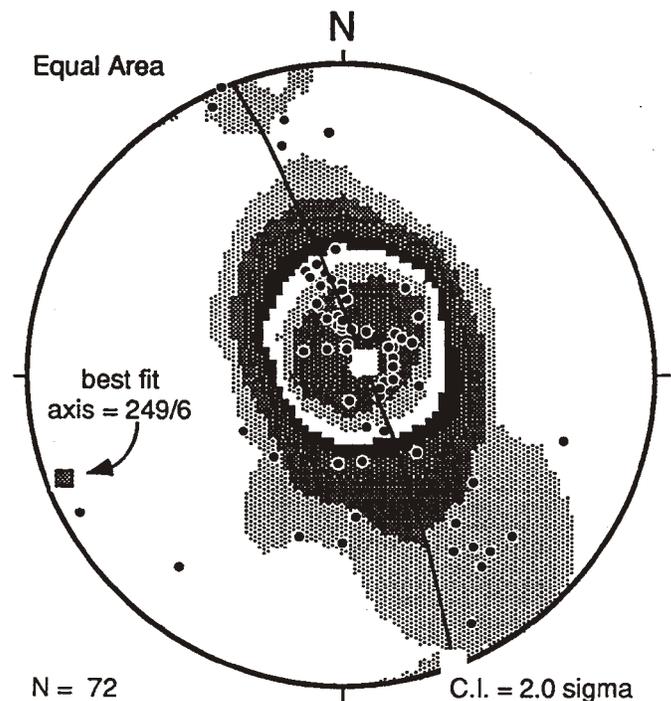


Figure 5. Millimagassett Lake region: poles to bedding (72).

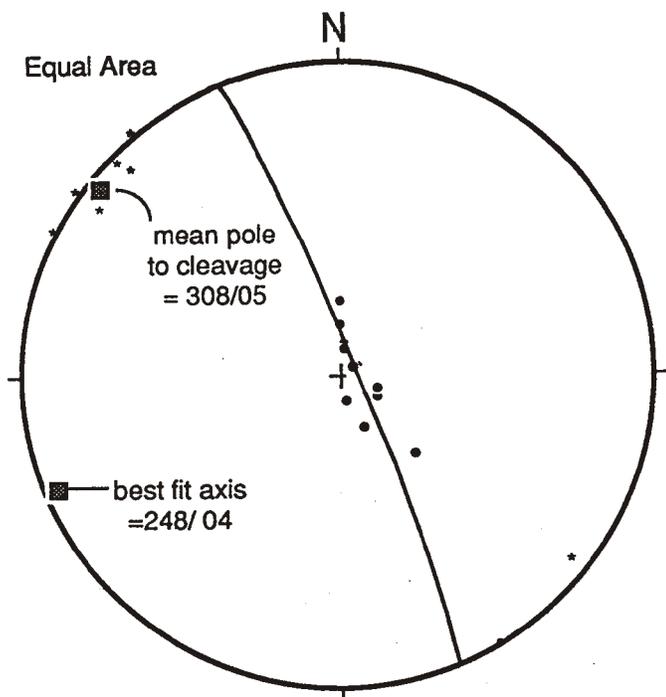


Figure 6. South shore of Millimagasset Lake. \bullet = poles to bedding around early fold (11), * = poles to late cleavage.

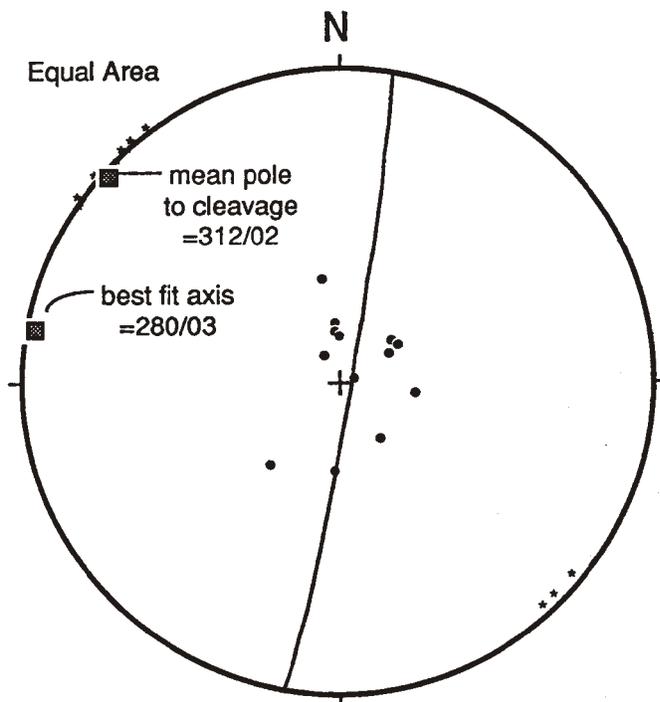


Figure 7. Outlet area of Millimagasset Lake: \bullet = poles to bedding around early fold (13), * = poles to cleavage (11).

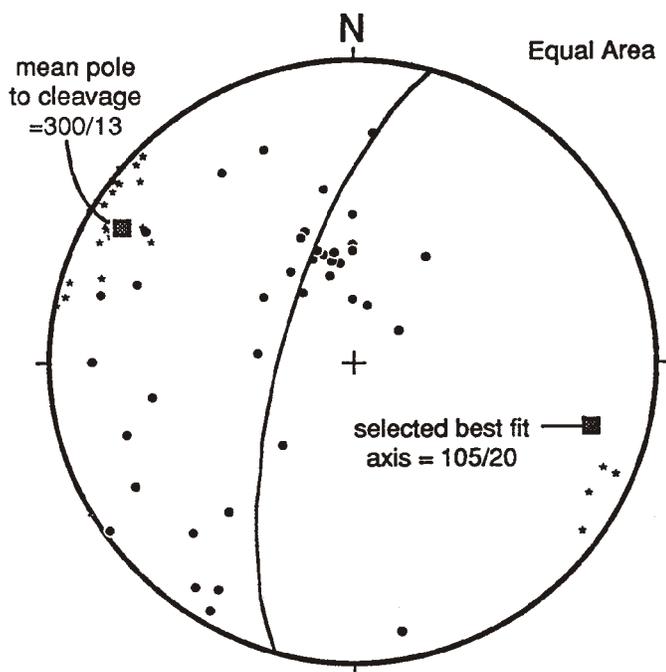


Figure 8. Scraggly Lake area: \bullet = poles to bedding around early fold (34), * = poles to late cleavage (25).

these second order folds plunge gently to the west-northwest (Fig. 7). The difference in trend of these folds is attributed to gentle warping of these intermediate phase folds around a late phase open fold that trends northeasterly.

In the area of Saddle Pond, where the Saddle Pond formation is apparently tectonically spliced with the Grand Lake Seboeis group, sparse stratigraphic younging indicators in narrow belts of the group suggest that these strata are folded into synclines (Fig. 4). These structures have the same orientation as the intermediate phase synclines around the lakes and are likely genetically related to them.

Intermediate phase minor folds are only locally developed in slaty to phyllitic members of all units except the Millimagasset Lake formation. They are manifest as a crenulation to open to close folding of the earlier foliations and bedding. In one place mentioned above, a zonal crenulation cleavage is axial planar to these folds. The intermediate phase minor fold axes have a general east-west trend with plunges varying from moderate to steep (Fig. 9). The minor folds likely are higher order folds related to the map-scale intermediate phase folds of similar orientation.

Faults: The major faults documented to date appear to envelope the southern outcrop belt of the Ireland Pond formation. The best documented fault in the area separates the Ireland Pond assemblage from the Millimagasset Lake formation and Grand Lake Seboeis group in the vicinity of Beaver Brook and is here termed the Beaver Brook fault. It is marked by steeply dipping,

northeast-trending shear fabrics in the felsic volcanoclastic rocks on Beaver Brook and elsewhere along strike as well as by what appears to be brecciated shear zone rocks in outcrops to the east-northeast. Shear bands, asymmetric quartz porphyroclasts, and subhorizontal mineral lineations in the shear zone at four locales indicate that there was a component of left-lateral motion along this fault. In one thin section of mylonitic felsic volcanic(?) rock, quartz has clearly deformed by crystal plastic mechanisms, as subgrain growth and recrystallized grains are abundant. However, it appears that the history of the fault is more complex than simply plastic deformation, as some quartz porphyroclasts appear to have initially deformed brittly by fracture and pulling apart and subsequently were subjected to plastic deformation. In addition, a narrow, 2-mm wide, cataclastic zone traverses the section parallel to the mylonitic foliation and incorporates breccia fragments of mylonitic rock in the zone. This zone appears to be a microscopic analog to the brecciated shear zone rocks found in outcrop.

In the area of Saddle Pond, it appears that a group of subparallel faults are responsible for interleaving the Saddle Pond formation with the Grand Lake Seboeis group. These faults appear to be steeply dipping for the most part, as their surface traces show little regard for topographic changes.

In the area of Saddle Brook and eastward, one of these faults separates the Saddle Pond formation from the Grand Lake Seboeis group. The trace of the fault appears to follow Saddle Brook and is thus termed the Saddle Brook fault. It is manifest by intensely foliated Grand Lake Seboeis rocks near the south

shore of Saddle Pond, local breccia east of Saddle Pond, and by intensely foliated quartz-sericite phyllite farther to the east. The sense of motion on the fault is uncertain, although the disposal of lithostratigraphic units suggests a major "north side up" component of motion.

Intensely foliated rocks are also found along the contact of the Ireland Pond assemblage and the Saddle Pond formation. On the logging road just west of Hay Brook, this fault abruptly places conglomerates of the assemblage against intensely foliated black phyllite of the formation. The kinematics of this fault are uncertain.

Interpretation: It appears that the three major map-scale features of the intermediate deformation phase, the folds, the Beaver Brook fault, and the Saddle Pond area fault system are geometrically related; this association suggests a genetic relationship for these structures. The major folds affect strata on either side of the Beaver Brook fault and their oblique orientation with respect to the fault is consistent with the left-lateral motion, determined by independent means for the fault. Both sheared rocks of the fault zone and the major folds are overprinted by the late phase cleavage. The Saddle Pond fault system is also oblique to the Beaver Brook fault zone and sheared rocks in this area are also overprinted by the late cleavage; the complex geometry of this area is highly suggestive of a positive flower structure, commonly found in convergent strike-slip regimes (Fig. 4). It is noteworthy that the extent of the Saddle Pond fault system coincides with a slight change in trend of the Beaver Brook fault, suggesting that the Saddle Pond fault system formed in response to this restraining bend in the fault. In addition, the intermediate phase foliations are most intensely developed near these faults; multiple generations of intermediate phase foliation generation are consistent with a shearing environment.

Thus it appears that the intermediate deformation phase records the kinematics of a major convergent strike-slip zone in the Saddle Pond-Grand Lake Seboeis area, involving left-lateral motion along the Beaver Brook fault and shortening oblique to the zone by folding and faulting. Judging from the scale and extent of the structures formed during this deformation, left-lateral motion is thought to have been significant. It is uncertain if the Beaver Brook fault is the principal displacement zone in the system, or just a subsidiary relay fault within a larger system. It is noteworthy that S. Hall (pers. commun., 1992) has recorded left-lateral shear sense indicators along a major fault that trends through Millinocket Lake, a mere 3 km to the northwest of the Beaver Brook fault; this suggests that the convergent strike-slip system may be wider than currently realized.

Late Phase

Foliation and Folds: The late phase foliation is the most widespread foliation in the area and is generally recognized by its consistent northeasterly trend and steep dip (Fig. 10) and overprinting relationships with any earlier fabrics. It is the dom-

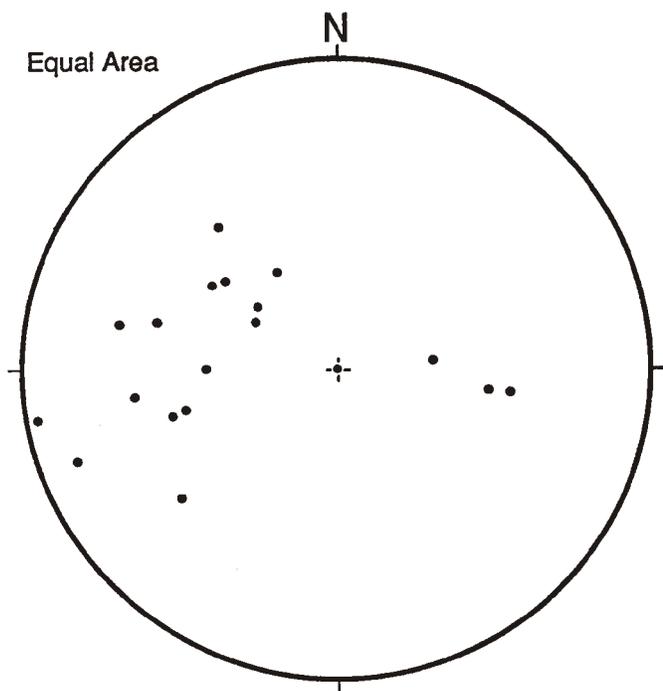


Figure 9. Intermediate phase minor fold axes (19).

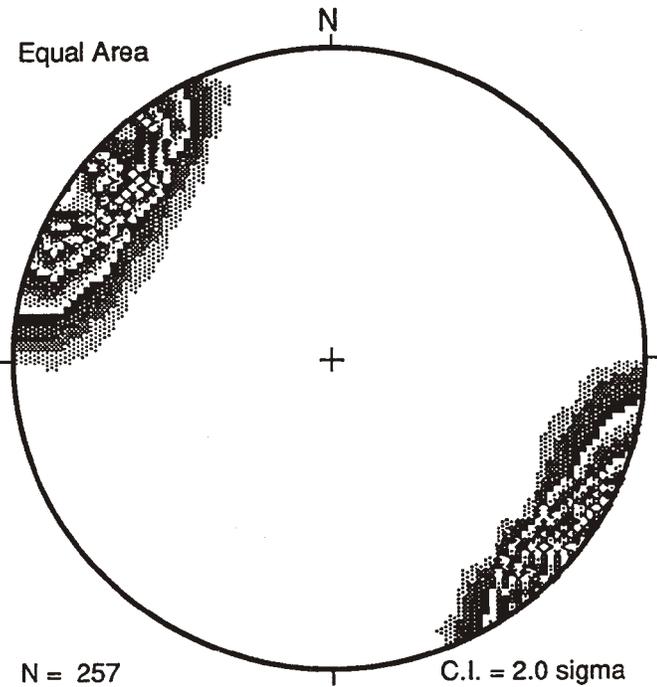


Figure 10. Grand Lake Seboeis - Saddle Pond Region: Poles to "late Acadian" foliation.

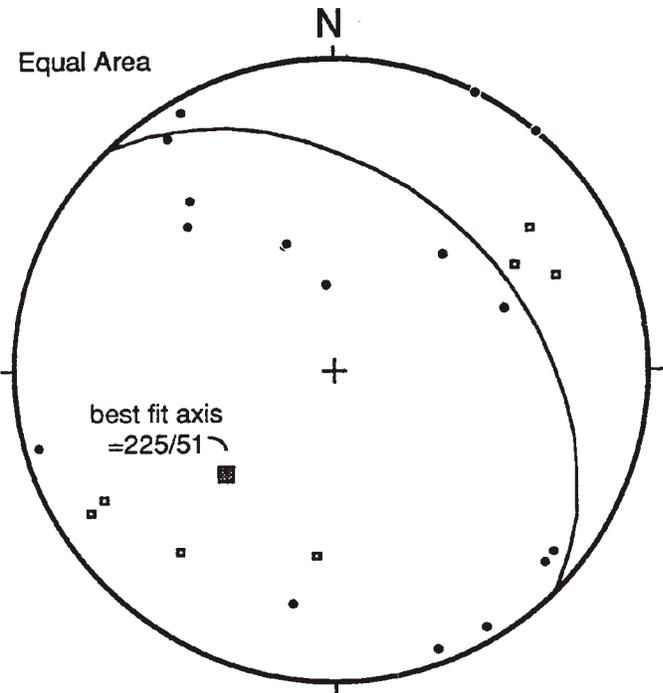


Figure 11. Boody Pond area slate: \bullet = poles to layering / early cleavage, \blacksquare = late minor fold axes.

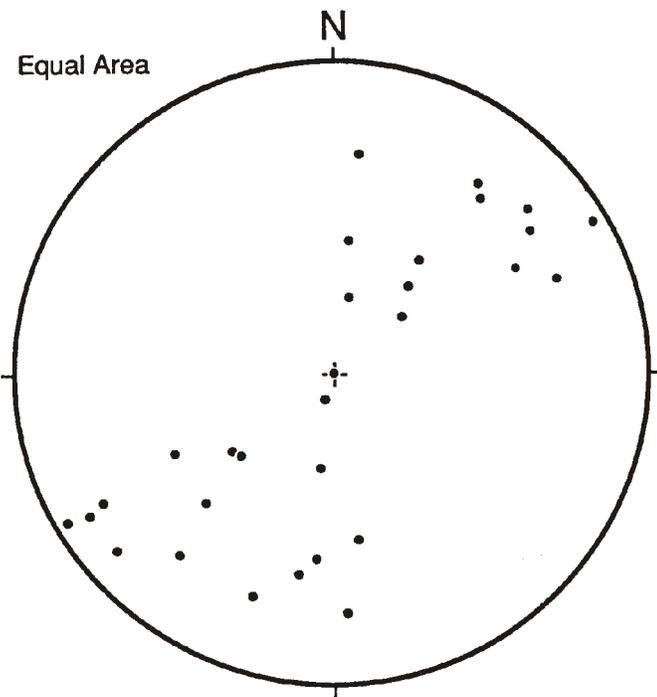


Figure 12. Late phase minor fold axes.

inant penetrative fabric in all of the Millimagassett Lake formation and almost all of the Grand Lake Seboeis group; it is generally manifest as a slaty cleavage in most of the rocks except for the more massive sandstones, conglomerates, and volcanic rocks, where it is difficult to detect, but locally present. Only in the phyllites and sandstones in the narrow outcrop belt of the group north of Saddle Pond is this phase manifest as a crenulation of earlier fabrics. In the Ireland Pond belt and Saddle Pond formation, the late deformation is generally developed as either a spaced crenulation cleavage or solely as crenulations of earlier phase fabrics.

The late phase foliation is locally axial planar to both minor folds and major folds in bedding and crenulations of the early layer-parallel foliation. These folds range from open chevron folds to close, nearly concentric folds. The larger folds appear to be broad and open; the best examples of these are the warp in trend of stratigraphic units and intermediate phase structures in the Millimagassett Lake area and the sweeping change of trend of the intermediate phase fabric in the slate of the Ireland Pond assemblage to the northwest of Grand Lake Seboeis (Fig. 11). In all of the units, the major and minor fold axes trend northeast-southwest (Figs. 11, 12); however, the plunge of these folds varies considerably. The variation in late minor fold axes may have resulted from the variation in trend of layering prior to the late deformation.

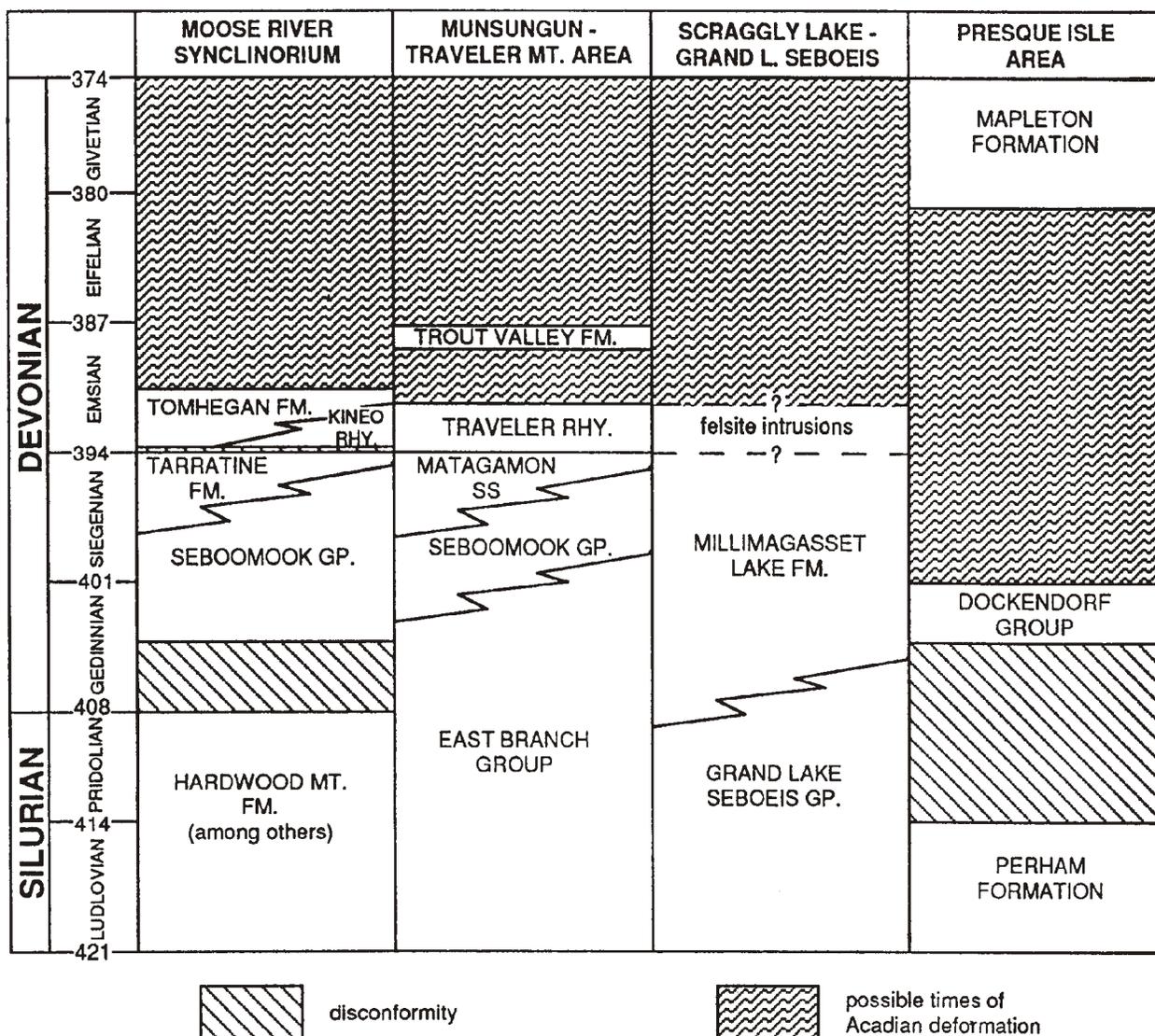


Figure 13. Timing of Acadian events in north-central Maine.

In summary, the late phase cleavage and folds appear to record an episode of northwest-southeast directed shortening. It is likely that faulting and reactivation of earlier structures accompanied this event, although direct evidence of such kinematics are sparse at this time.

Timing of Deformation

The timing of deformational events in the Saddle Pond-Grand Lake Seboeis region is very loosely constrained by the local geology. Perhaps it is easiest to place a “cap”, or younger limit, on the deformation scheme, thus the discussion starts with the timing of the late deformation.

The late phase appears to affect all rocks in the area and hence must be younger than the felsites and gabbros. The felsites may be correlative with the Traveler rhyolite, indicating that the

late phase shortening in the region may be post-early Emsian. The late phase deformation displays the identical characteristics as the classical Acadian orogeny that is documented throughout northern Maine (Fig. 13) (e.g. Osberg et al., 1989; Hall, 1970; Boucot, 1968). Throughout the region, the Acadian upright folding and cleavage formation affects Siegenian rocks and locally affects rocks as young as early Emsian (Boucot and Heath, 1969). The younger limit on the Acadian event is not as clear as the older constraint. In the Traveler Mountain area, the Acadian deformed Traveler rhyolite is unconformably overlain by the slightly deformed Trout Valley Formation of latest Early Devonian to earliest Middle Devonian age (Dorf and Rankin, 1962; Kasper, 1980). This suggests that the Acadian orogeny in this area was confined to the short time span of the late Emsian. However, in the regional area of New England and Maritime Canada, stratigraphic constraints indicate an early Middle Devo-

nian timing for the main pulse of the Acadian orogeny (Boucot, 1968). Consequently, it has been suggested that the Trout Valley Formation has been shielded from most affects of the Acadian orogeny by the competent underlying Traveler rhyolite (Rankin, 1968). Thus it appears that the late phase deformation in the Saddle Pond-Grand Lake Seboeis region is of either late Early Devonian or early Middle Devonian age.

The intermediate phase deformation affects all strata in the area and is overprinted by the late phase deformation; thus the intermediate phase must be of Early Devonian age. The effects of this event are quite heterogeneous, as it affects the Ireland Pond assemblage more uniformly than the Grand Lake Seboeis group. Coarse conglomerates and rapid facies changes in the group suggest that possibly tectonism accompanied deposition in this region. Thus it is possible that convergent strike-slip tectonics were time transgressive and could have initiated in the Silurian and proceeded into the Early Devonian.

The intermediate phase deformation has not been previously recognized in the region. It is apparently an early phase of the Acadian orogeny in this area. Further investigation into its geometry, kinematics and timing should add another dimension to our understanding of the complex Acadian orogeny in the northern Appalachians.

The early phase deformation that affects the Saddle Pond formation superficially appears to resemble early fabrics in the Ireland Pond assemblage and portions of the Grand Lake Seboeis group. This would suggest a Silurian or younger time of deformation for the early phase. However, Saddle Pond-correlative rocks of the Arenig Chase Brook Formation to the northwest display a similar strong layer-parallel foliation and are unconformably overlain by the Middle Ordovician Chase Lake Formation (Hall, 1970). Thus it is suggested here that the Saddle Pond formation early foliation may also be confined to the short time between Arenig deposition and the Middle Ordovician unconformity found in the Munsungun anticlinorium.

ACKNOWLEDGMENTS

Foremost, I thank Gary Boone for an introduction to the geology of the Saddle Pond area and for his encouragement to pursue a field program there. I am grateful to Robert Marvinney and Walter Anderson of the Maine Geological Survey for essential funding of the program as well as facilitating logistical aspects of the study. I thank Robert Neuman for numerous discussions, field consultation, preliminary paleontological identifications, and for providing me with his reconnaissance field maps of portions of the area. Drs. Arthur Boucot, William Oliver and Svend Stouge are thanked for their ongoing efforts in paleontological identification. Steve Hall is acknowledged for field assistance (1990) and for discussions of the local geology. The "Gulls", Kevin Wilkins and Kevin Hoff are thanked for field assistance (1991).

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APPENDIX (new paleontological data)

GRAND LAKE SEBOEIS GROUP

R. Neuman identifications:

Sample A-36: Frost Pond 1:24,000 quad., Piscataquis County, T7R9, UTM grid location, 0508.24E, 5120.05N.

A few brachiopods, including a chonetid and an unidentified species of *Atrypa*. The latter indicate a Silurian or Early Devonian age.

This assessment refined to Upper Llandovery-Early Devonian by A. Boucot.

Sample A-4: Trout Brook Mountain 1:24,000 quad., Penobscot County, T7R8, UTM grid location 0514.80E, 5118.96N.

The following brachiopods were identified (listed taxonomically, following the classification of the treatise of Invertebrate Paleontology, Part H. The number of specimens identified is indicated in parentheses): *Ptychopleurella* sp. (1), *Dictyonella* sp. (1), enteletaceans indet. (13), *Isorthis* sp. (1), *Dicoelosia* cf. *D. biloba* (Linnaeus) (5), *Plectodonta* (*Plectodonta*) sp. (2), *Leptaena* sp. (3), chonetid? sp. (1), atrypacean gen. indet. (1), *Atrypina?* sp. (1), delthyrid? gen. indet. (1).

Indicates Late Silurian (Ludlow) to Early Devonian (Lochkow) age.

This assessment refined by A. Boucot to Upper Silurian.

A. Boucot identifications:

Sample E-13: Millinocket Lake East 1:24,000 quad., Piscataquis County.

This is a Pridoli age locality, featuring *Eccentricosta* sp. as the datable item, plus *Coelospira* sp., *Howellela* sp., *Atrypa* "reticularis", *Leptostrophia?* sp., "Camarotoechia" sp.

Sample SB-33: Millinocket Lake East 1:24,000 quad., Penobscot County.

Lissatrypa sp., *Resserella* sp., *Dicoelosia* sp., *Coelospira* sp., *Dalejina?* sp., *Leptaenisca* sp., trilobite, *Leptaena*

"*rhomboidalis*", stropheodontids. This is an Upper Silurian age collection.

W. Oliver identifications:

Sample A-50: Trout Brook Mountain 1:24,000 quad., Piscataquis County, T7 R9, UTM grid 0511.60E, 5119.365N.

Stauromatidium sp. cf. *S. marylandicum* (Swartz), 1923., rugose corals, favositid corals.

Age: I am confident of the Pridolian-Lochkovian range and lean slightly toward a Lochkovian age.

S. Stouge identifications:

Sample HS-34: Trout Brook Mountain 1:24,000 quad., Piscataquis County. Clast in conglomerate.

Conodont fauna: (?) *Kockelella* sp. (3)

Age of conodont fauna: *Kockelella* Walliser, 1957, has a stratigraphic distribution from Upper Llandovery to Ludlow.

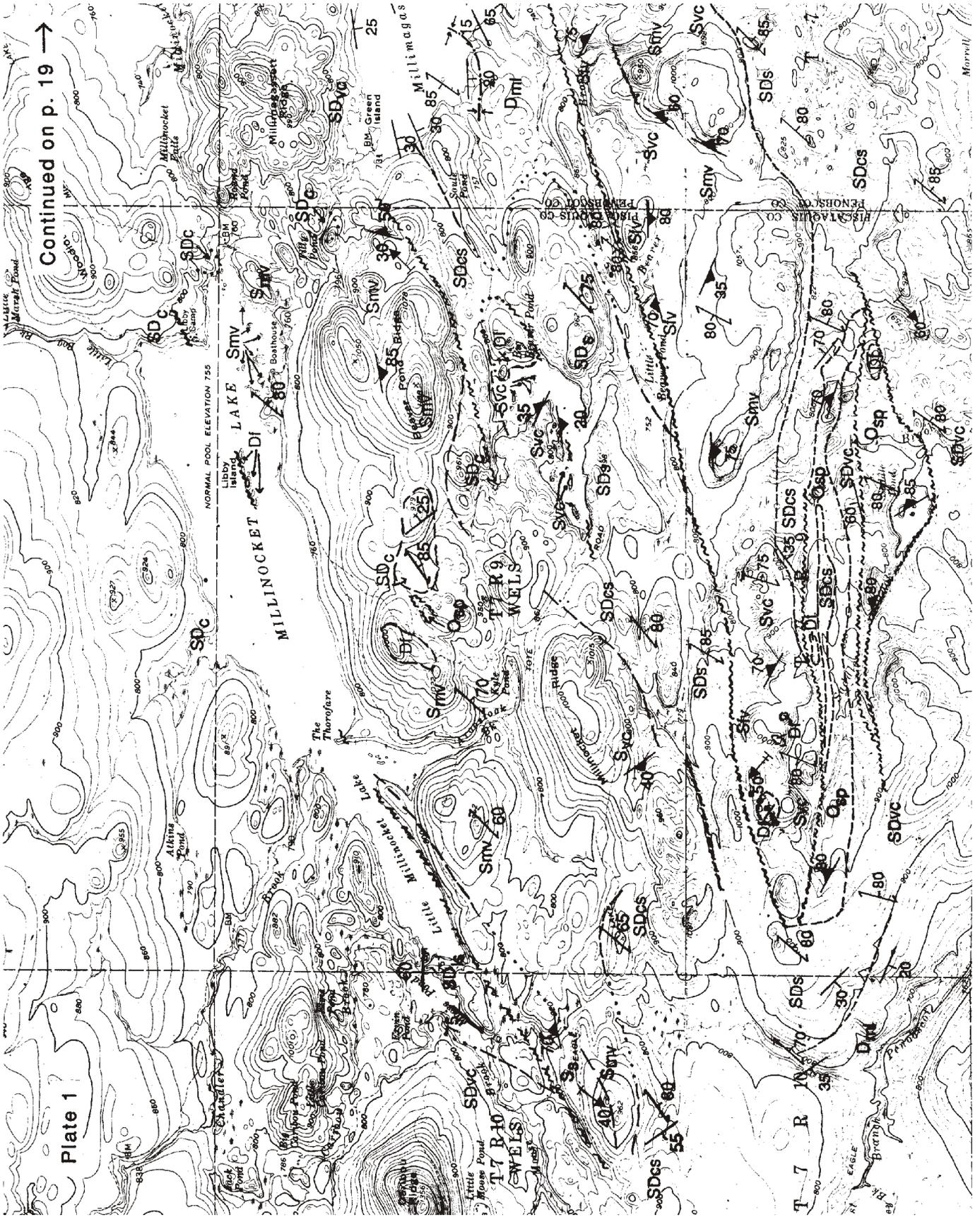
Other fauna elements: trilobite, gastropod, and an ostracod.

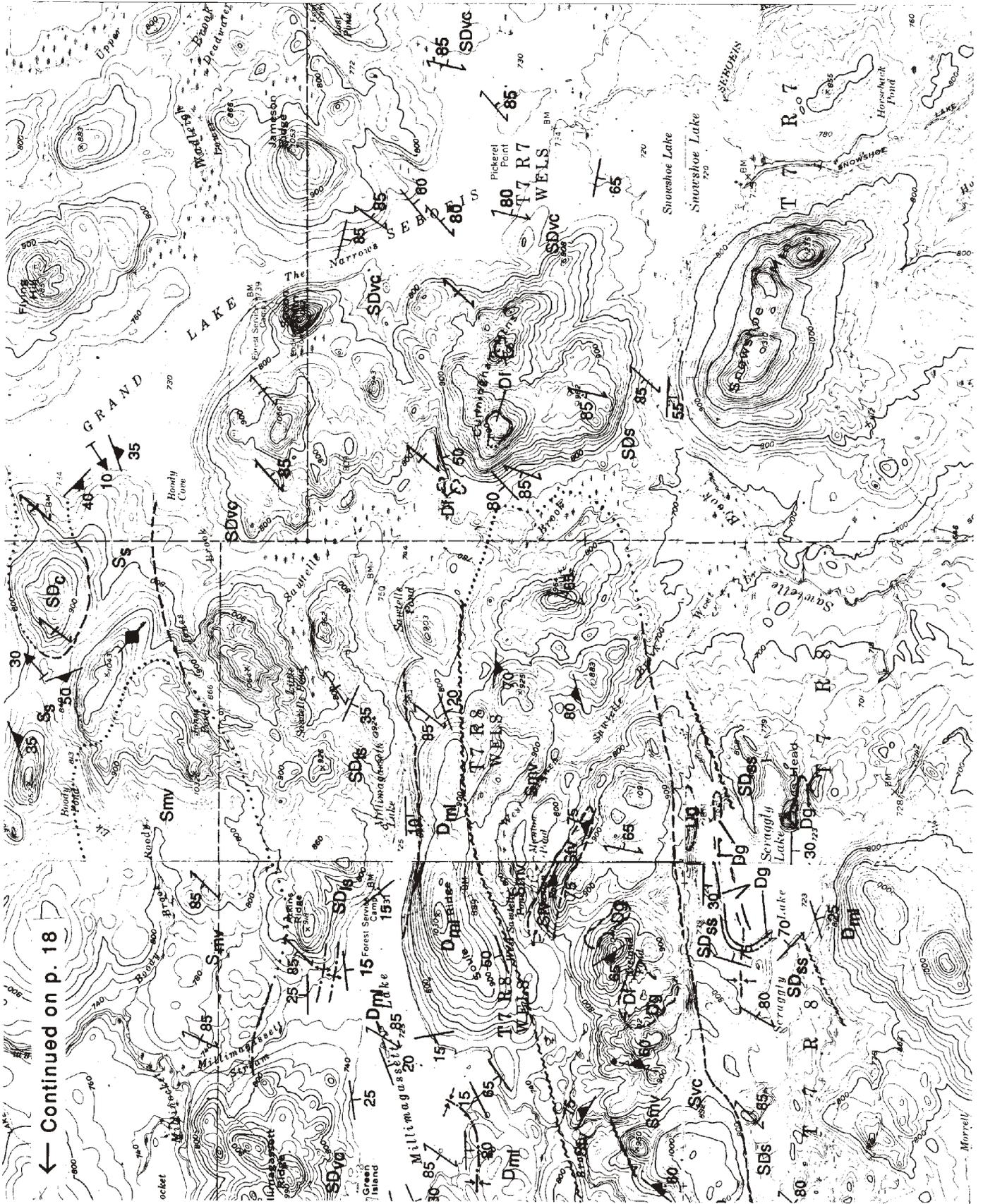
MILLIMAGASSETT LAKE FORMATION

A. Boucot identification:

Sample SB-44: Grand Lake Seboeis 1:24,000 quad., Penobscot County.

This one is hard to date. It's somewhere in the Upper Silurian-Heldeberg interval - assuming that one wouldn't expect *Coelospira* and a strophonellid in the local Oriskanian beds. I got a large *Coelospira* sp., "*Neumenella*" ?? sp., trilobites, tetracorals, pelmatozoan debris, "*Camarotoechia*" sp., *Strophonella?* sp., dalmanellid.





← Continued on p. 18

LEGEND

DEVONIAN

Df felsite and felsitic breccia

Seboomook Group

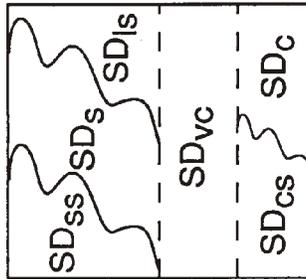
Dg gabbro

Dml

Millimagassett Lake formation: mainly alternating, thin to medium-bedded brownish-gray sandstone and shale.

DEVONIAN - SILURIAN

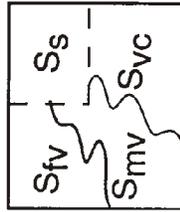
Grand Lake Seobeis group



SD_{ss}: Scraggly Lake sandstone: mainly medium to thick-bedded fine-grained frosty graysandstone; minor shale. **SD_s:** mainly gray slate; minor siltstone and sandstone interbeds. **SD_{Is}:** mainly fossiliferous light gray calcareous slate, commonly with carbonate pods and interbeds. **SD_{vc}:** varied assemblage of rhyolitic to basaltic volcanic and volcanoclastic rocks and clastic sedimentary rocks. **SD_{cs}:** clastic sedimentary rocks, including cobble to boulder conglomerate, sandstone, and slate. **SD_c:** mainly cobble to boulder conglomerate.

SILURIAN (?)

Ireland Pond assemblage



S_s: varicolored slate; in many places shows polyphase deformational features. **S_{fv}:** mainly felsic volcanoclastic rocks. **S_{mv}:** mainly mafic volcanic and volcanoclastic rocks. **S_{vc}:** mainly mafic volcanoclastic rocks.

ORDOVICIAN (?)

Saddle Pond formation

Osp

mainly intensely deformed gray to black phyllite with subordinate quartz-graywacke and minor thin carbonate interbeds.

SYMBOLS

- bedding
- late phase cleavage
- early foliation ± layering
- late phase minor fold
- earlier phase minor folds
- contact (observed, approximate, assumed)
- faults (observed, approximate, assumed)
- early phase major fold axes

Part 2: Preliminary Report on the Geology of the Western End of the Grand Lake Seboeis Inlier, North-Central Maine

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INTRODUCTION

The Grand Lake Seboeis inlier is the informal name given here to the group of Early Paleozoic rocks shown on and to the west of Grand Lake Seboeis, north-central Maine, on the 1985 state geologic map (Osberg et al., 1985). This investigation has concentrated on the western end of the inlier, specifically, the portion that lies within Piscataquis county. During the 1991 field season, six weeks of systematic, detailed (1:24,000) geologic mapping were completed. The mapping has been done on the USGS Millinocket Lake East and Millinocket Lake West 7.5' quadrangles. Access to the area is primarily via Huber Co. logging roads and trails. The primary objective of the 1991 field season was to begin to establish a bedrock geologic map of the western end of the inlier, concentrating on lithologies and distribution of rock types. The field work for this project will be completed in the 1992 season. See Part 1, Figure 1 for location. The results of this mapping are included in the geologic map (Plate 1).

Previous Work

The most detailed published geologic map of the Grand Lake Seboeis inlier is the 1985 Maine State bedrock geologic map (Osberg et al., 1985). Limited reconnaissance excursions into the area were made by Dr. R. B. Neuman and Dr. B. A. Hall, who were mapping areas to the southeast and northwest, respectively. This reconnaissance work is the basis for the Cambro-Ordovician anticlinorium representation of the area on the 1985 state geologic map. These ages have been assigned primarily on the basis of lithic and structural correlation with rocks exposed in the Munsungun and Lunksoos inliers to the NW and SE, respectively, of the Grand Lake Seboeis inlier. In contrast, this investigation suggests that the bulk of the rocks in the western end of the inlier are heterogeneously deformed and probably Siluro-Devonian in age.

Regional Geologic Setting

The Grand Lake Seboeis inlier lies within the northern Maine belt of Berry and Osberg (1989). Within this regional belt it appears to lie between Early and Middle Paleozoic anticlinoria that were deposited on contrasting basement rocks. The Early and Middle Paleozoic rocks of the Lunksoos anticlinorium to the southeast are interpreted to have been deposited on Late Precambrian-Cambrian age continental margin sediments (Neuman, 1967). Similar age rocks of the Munsungun anticlinorium to the northwest appear to have been deposited on ophiolitic basement (Osberg et al., 1985). The nature of the transition zone between these contrasting basement types is at present uncertain.

LITHOLOGIES

During the 1991 field season, several lithologic packages of volcanic and/or sedimentary rocks were recognized in the western end of the inlier. These lithologic packages bear some resemblance to those recognized by Hibbard (1991) in the Saddle Pond inlier and the eastern part of the Grand Lake Seboeis inlier. These informal divisions are: (1) a heavily deformed metasedimentary unit, (2) the Millinocket Lake belt mafic to felsic volcanic and volcanoclastic rocks, and (3) a varied sequence of sedimentary rocks, primarily conglomerate, slate, and sandstone. Fault related rocks were also observed as were stocks of gabbro and felsite. Rocks interpreted to be equivalent to the Seboomook Formation have been mapped around the inlier as well. All rocks in the inlier and the surrounding Seboomook Formation as well have been affected by Middle Paleozoic low-grade regional metamorphism.

Unnamed Gray Phyllite Unit

General: The unnamed gray phyllite unit is volumetrically a minor component of the west end of the inlier, however, it is a distinct lithology. This unit is primarily composed of highly disrupted gray to black phyllite with minor amounts of quartz-rich graywacke. It is only observed in one outcrop location, in a small quarry along a northeast section of the major access road, NNE of Kyle Pond. The outcrop width is about 75 m, although true thickness is uncertain. At the western edge of the exposure, mafic volcanic rocks of the Millinocket Lake belt outcrop less than 5 meters from the phyllite and the contact between the two is interpreted to be a northeast-trending fault. The evidence for this is the brecciated and veined nature of the volcanic rocks near the contact and the disruption evident in the phyllite unit. Contacts to the east and south have not yet been observed. Layering in the unit is northeast-trending and steeply to vertically dipping. This rock is very fissile and is used extensively throughout the area as road metal.

Rock Description: This unit is primarily a gray to black phyllite with minor amounts of quartz-rich graywacke. The phyllite weathers to white or light gray color and calcite andankerite veining is pervasive. The unit displays laminations, manifest in alternating medium and dark gray fine-grained banding. Individual layers range from 1 to 15 mm in thickness and are discontinuous. This lamination is only locally observed on the outcrop. The lamination also appears to be parallel to the regional foliation where observed. The interlayered(?) graywacke contains coarse to fine sand size quartz, occasionally with a bluish hue and a gray silty matrix. This quartz wacke occurs as discontinuous lenses or disrupted layers within the phyllite. It appears that the lenses are boudinaged layering with individual boudins considerably removed from each other.

Age and Correlation: No fossils or other datable evidence for age were observed in this unit during inspection in the 1991 season. It appears to be of higher metamorphic grade than other rocks of the western end of the inlier, although this may be a result of locally intense deformation rather than an older age. This unit very closely resembles the Saddle Pond formation of the more southerly inlier mapped by Hibbard (1991, this report, Part 1). Hibbard suggests the Saddle Pond Formation bears some degree of resemblance to the upper black slaty member of the Cambrian Grand Pitch Formation of the Lunksoos anticlinorium (Neuman, 1967). He also suggests a possible correlation with the Chase Brook Formation of the Munsungun anticlinorium, based on the Grand Pitch-Chase Brook correlation by Hall (1970). These correlations are based on both lithologic similarity and structural history of those formations. There is no evidence refuting this correlation of the Saddle Pond Formation and the gray phyllite-quartz wacke of the Grand Lake Seboeis with either the Chase Brook or upper Grand Pitch Formations revealed during this investigation. This could tentatively suggest a Cambrian or Lower Ordovician age for the unnamed gray phyllite unit.

The Millinocket Lake Belt

General: The Millinocket Lake belt is the informal name applied here to the belt of primarily mafic rocks with minor felsic volcanic and associated volcanoclastic rocks that extends from the southwestern corner of the Millinocket Lake West 7.5' quadrangle to the eastern end of Millinocket Lake in the west-central section of the Millinocket Lake East 7.5' quadrangle. The rocks of this belt bear some lithologic resemblance to those of the Ireland Pond belt in the Saddle Pond inlier (Hibbard, 1991), however, little other evidence supports the correlation at this time. The belt is dominated by mafic volcanic rocks along its northwestern flank, however, the amount of intermediate and felsic volcanic and volcanoclastic rocks generally increase to the southeast. The true thickness of the Millinocket Lake belt is uncertain due to lack of bedding features and structural complexity. It has a maximum outcrop width of 3.3 km between southwestern Millinocket Lake and Millinocket Ridge. Layering has highly variable attitude within this belt while the overprinting Acadian foliation is consistently northeast-striking and steeply inclined. The contact of the Millinocket Lake belt rocks with the unnamed gray phyllite unit is a fault and has been discussed in the previous section. The contact of the Millinocket Lake belt rocks with the Grand Lake Seboeis group has not been observed to date although exposures of each lie within a few dozen meters of each other in several locations. Minimal evidence suggests either conformity or unconformity along most of the contact. A fault has been observed along a portion of the contact east and south of Beaver Pond Ridge.

Rock Descriptions: *Mafic volcanic and volcanoclastic rocks* are most prevalent and least deformed in this belt at the eastern end of Millinocket Lake where pillow basalts crop out along the lake shore and on most of the islands in the lake. Massive basalts outcrop in the central and southwestern areas of the belt. Where pillow basalts are exposed, they are typically less than 1.2 m in diameter and as small as 0.5 m in diameter and the pillows are locally brecciated. Phenocrysts occur only rarely in both types of lavas and are small, less than 10 mm plagioclase or pyroxene crystals. The lavas are locally amygdaloidal. Tan to gray-green chert comprises the interpillow material when present. Numerous dikes and plugs of fine- to coarse-grained gabbro intrude the pillow and massive lavas, however, they are commonly below map resolution at 1:62,500 scale.

Mafic volcanoclastic rocks are associated with the lavas and are more prevalent along the southeastern section of the belt. They are primarily chloritic phyllite and volcanic conglomerate. The phyllite is primarily composed of chlorite with epidote and quartz forming thin, <10 mm thick, layering locally. The layering is discontinuous and lensey, with lenses generally less than 40 cm long.

Mafic volcanic conglomerate is somewhat less abundant than the chloritic phyllite in this belt. It generally has a chlorite-epidote-quartz-feldspar fine to coarse sand matrix and clasts are primarily mafic volcanic and volcanoclastic. The ob-

served clasts are matrix supported, range in size from 2 mm to 30 cm and vary from angular to rounded. An unusual example is well exposed on the southeast side of Millinocket Ridge where the matrix is purely dark green chlorite and the clasts are mafic and intermediate volcanic and light-colored layered sedimentary material that appears to have been both faulted and stretched, perhaps nontectonically.

Intermediate volcanic and volcanoclastic rocks are in greater abundance along the southern section of the belt. Intermediate volcanic and volcanoclastic rocks, predominantly micaceous to weakly chloritic fine-grained and conglomeratic volcanoclastic rocks, are exposed on the islands and northwestern shores of Big Beaver Pond. The fine-grained rocks show millimeter-scale laminations with lighter layers consisting of fine-grained clays, white micas, and quartz and darker layers of chlorite, epidote, and quartz. A small amount of carbonate, light gray micritic limestone, was found to be locally interlayered within the volcanoclastic rocks. The conglomerate has a medium gray-green fine-grained matrix and fine-grained light gray epiclastic clasts that range in size from 5 to 40 cm in length and appear consistently flattened parallel to foliation. Intermediate volcanic rocks crop out on Big Beaver Pond as well. These volcanic rocks have light gray fine-grained tuffaceous matrix and 0.5 mm phenocrysts of pyroxene. More felsic rocks have been observed in the belt, but only in very minor proportions when compared to the intermediate and mafic rocks. Medium pinkish gray feldspar-phyric volcanic rocks were observed to be interlayered with intermediate to mafic volcanic rocks in one location just north of Beaver Pond Ridge. This felsic rock has K-feldspar phenocrysts about 5 mm long in a very fine-grained matrix of quartz and feldspar. Other felsic rocks in the belt are interpreted to be intrusions and are discussed in that section.

Age and Correlation: Examination during the 1991 field season revealed no direct evidence for the age of the rocks of the Millinocket Lake belt. In several locations where outcrops lie close at hand, gently dipping upright rocks of the Grand Lake Seboeis group appear to overlie inclined(?) Millinocket Lake belt volcanic rocks. This contact has not yet been observed, however. While it is possible that the sedimentary rocks of the Grand Lake Seboeis group are interlayered with the Millinocket Lake belt volcanic rocks, it appears more plausible that the Grand Lake Seboeis group may overlay the Millinocket Lake belt volcanic rocks, perhaps unconformably. Grand Lake Seboeis group rocks have yielded Late Silurian-Early Devonian fossils in the Saddle Pond inlier and Late Silurian age fossils have been identified from Grand Lake Seboeis group rocks in the western end of the Grand Lake Seboeis inlier. This suggests that the volcanic rocks of the Millinocket Lake belt are not younger than Late Silurian in age.

Grand Lake Seboeis Group

General: The Grand Lake Seboeis group (this report, Part 1) is the informal name given to the mixed assemblage of pre-

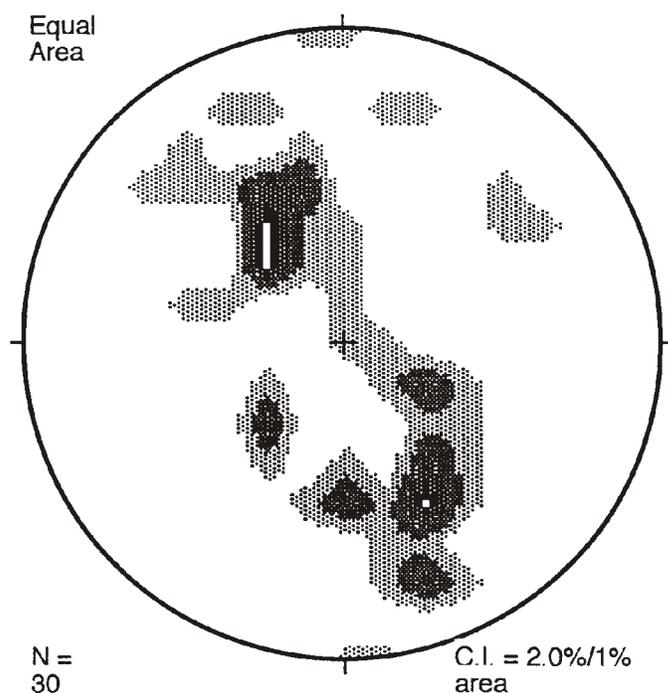


Figure 14. Poles to bedding within the Grand Lake Seboeis group.

dominantly clastic sedimentary and varied volcanic rocks that crop out throughout the Saddle Pond and Grand Lake Seboeis inliers. In the western end of the Grand Lake Seboeis inlier this group is represented by its sedimentary members only. There the group consists primarily of conglomerate and slate with subordinate amounts of sandstone and clastic carbonates. These rocks lie along the flanks of the western end of the inlier and occur within the inlier as well. The contacts have not yet been observed closely enough to discern whether these rocks which crop out within the Millinocket Lake belt are erosional outliers or are interlayered with the volcanic belt. The contact with the Millinocket Lake belt is interpreted to be a fault southeast of Big Beaver Pond due to severely deformed volcanoclastic rocks that lie along the boundary between these distinct packages of rocks. This group appears to be overlain conformably by the Millimagasset Lake formation of Hibbard (1992) in the southeastern area of this investigation, along the eastern shores of Little Beaver Pond. The thickness of the strata within this belt is uncertain. Maximum outcrop width is just less than 2 km along the southeastern flank of the inlier. Figure 14 summarizes bedding orientation in the group.

Rock Descriptions: *Conglomerate* in this group typically has a red sandy to silty matrix and a wide variety of clast lithologies. Rarely a bluish-gray-green matrix is observed, with no difference in clast content. The exact proportion of clast types varies from outcrop to outcrop. The granule to small boulder sized clast lithologies include, in order of decreasing abundance, mafic to intermediate fine-grained volcanic rocks, volcanoclastic

rocks, vein quartz, various colored mudstones, slates and sandstones, conglomerate, black and gray phyllite, quartz wacke, granitic rocks, and cherty material. Bedding is not commonly observed in the conglomerate, except where sandstone beds are associated with it. Outcrops tend to be massive, structureless, and weakly to non-foliated.

Sandstone of the Grand Lake Seboeis group is typically reddish gray in color and consists of silt to granule size material. The sand grains are angular to subangular and are primarily quartz and feldspar. The sands are medium bedded, with the sandstone commonly occurring as 1-2 m thick layers in the red matrix conglomerate. The sand beds show fining upwards and no overturned beds have been observed.

Slate in the Grand Lake Seboeis group is typically dark gray and featureless, however, thin, <5 mm thick graded silt to fine sand layers are locally observed. A few outcrops of maroon to red slate have been observed in proximity to red conglomerate and sandstone. The slate weathers to a light gray to white color. It crops out primarily along the southern flank of the western end of the inlier, and appears to conformably, perhaps gradationally underlie the Millimagasset Formation.

Fossiliferous calcareous siltstone, limestone conglomerate and limestone are observed on Moose Pond at the southwestern end of Millinocket Lake, and calcareous siltstone and limestone are exposed along the Soule Pond road approximately 1 km NW of Soule Pond. The calcareous siltstones vary from those that are fine-grained and featureless to some that contain 10 cm thick graded beds of fine sand to slate. On Moose Pond, limestone conglomerate was observed that contained up to 30-cm rounded clasts of fossil-rich micrite in a medium gray calcareous silt matrix. Dark gray impure limestone and medium gray calcareous siltstone closely associated with red matrix conglomerate and sandstone from the Soule Pond road yielded macrofossils that were examined by Dr. A. Boucot and the results of his examination are shown below.

Sample E-13 Millinocket Lake East 1:24,000 quad., Piscataquis County, UTM grid location 0513.5E, 5125.2N, "This is a Pridoli age locality, featuring *Eccentricosta* sp. as the datable item, plus *Coelospira* sp., *Howella* sp., *Atrypa reticularis*", *Leptostrophia?* sp, "*Camarotoechia*" sp."

Age and Correlation: The above fossil locality within the Grand Lake Seboeis group rocks of the western end of the inlier indicates a Late Silurian age for the group. Several fossil localities in the Grand Lake Seboeis group of the Saddle Pond inlier have yielded Late Silurian-Early Devonian ages as well, supporting the correlation of these lithologically similar rocks with those elsewhere in both inliers. These rocks also bear a strong resemblance to the descriptions of the East Branch Group rocks of the Munsungun anticlinorium (Hall, 1970) and the date given for the Grand Lake Seboeis group is similar to that for the East Branch Group.

Unnamed Slate(?) Unit

An unnamed slate unit has been separated from other lithologies in the inlier due to its restricted occurrence and the unusual features observed therein. This unit crops out along the southeastern shores of Little Millinocket Lake and along strike to the southwest. It is a lavender phyllitic slate that locally has interlayers of light green phyllitic slate. The rock has a Pre-Acadian(?) foliation that trends NE and dips at a very gentle angle and is clearly overprinted by a NE-trending, vertical, spaced crenulation cleavage. This rock may represent a highly deformed zone of slate such as that in the Grand Lake Seboeis Group. Further explanation of the importance of this rock type is pending more detailed investigation.

The Millimagasset Lake Formation

The rocks referred to by Hibbard (this report, Part 1) and herein as the Millimagasset Lake formation are cyclically bedded fine-grained tan to gray sandstone, fining into medium to dark gray slate. The beds are typically less than 15 cm thick. Based on strong lithologic resemblance, this unit is likely correlative with portions of the Seboomook Group which blankets large portions of northwestern Maine. This unit crops out along the eastern end of Big Beaver Pond and to the northeast between Little Beaver Pond and Soule Pond. Bedding has not been observed to be overturned. The age of this unit elsewhere in the region is considered to be Lower Devonian (Neuman, 1967, Hall, 1970).

INTRUSIVE ROCKS

Both mafic and felsic rocks appear to intrude the volcanic and sedimentary rocks of the Grand Lake Seboeis inlier. Coarse (<1 cm) to fine (<1 mm) grained gabbro that varies from fresh to severely chloritized intrudes rocks of the Millinocket Lake belt. The mafic intrusive rock primarily consists of pyroxene and plagioclase. Fine-grained gabbro (diabase) intrudes the sedimentary rocks of the Grand Lake Seboeis group as well. Individual gabbro bodies do not form large nor continuous exposures, but may be in the form of dikes instead of stocks. The intrusive rocks are typically massive and non-foliated, however a few are weakly to strongly foliated.

Felsic intrusive rocks appear to exclusively intrude the Millinocket Lake belt. Stocks of tan to white, beige weathering locally feldspar-phyric fine-grained felsite (dacite(?) to rhyolite) occur on the northeastern corner of Big Beaver Pond, on Libby Island in Millinocket Lake, and on a hilltop 2 km southeast of the thorofare between Little Millinocket Lake and Millinocket Lake. These bodies are substantial in size, up to 1 km in diameter, as is the case for Libby Island. The felsites are typically affected

by a single weakly expressed foliation. A special case is the Libby Island exposure. This outcropping is massive, unfoliated, and appears to be locally intruded by gabbro on the south side of the island but becomes dark colored, severely foliated, fine-grained and hackly on the northern edges of the island. This is interpreted to be the result of a northeast-trending fault running along the northwest side of the island.

The age of the intrusions is uncertain. Those that are affected by regional foliation are presumably no younger than Middle Devonian. The unfoliated intrusive rocks may have been locally shielded from regional deformation or may be younger than Middle Devonian.

STRUCTURAL GEOLOGY

The western end of the Grand Lake Seboeis inlier has a complex Early and Middle Paleozoic structural history. This history includes the development of one or more foliations and an associated set of folds in all rocks of the inlier.

These multiple foliations are an “early” layer parallel foliation and a later crenulation. The unnamed gray phyllite and quartzwacke unit, parts of the Millinocket Lake belt, and the unnamed slate unit have all developed the early layer-parallel foliation. This is not to imply that the early, layer-parallel foliation was synchronously developed in these units. The only present evidence for dating of this foliation is that it is clearly overprinted by the later regional “Acadian” deformation, assumed to be Middle Devonian in age.

Planar Fabrics and Folds

The older of the planar fabrics observed in the area occurs in the unnamed gray phyllite unit, the Millinocket Lake volcanic belt and the lavender slate(?) unit. This fabric is penetrative and parallel to layering in these rocks. It generally displays gentle dip and varied north to east strike. Folding of these rocks is by crenulation of the layer-parallel fabric and has either northeast-trending axes, attributed to later Acadian overprint, or northwest-trending axes of uncertain affinity. If the gray phyllite unit correlates with the Chase Brook Formation, then the early fabric in this rock may be attributed to an Early Paleozoic deformation. This is not, however, a satisfactory explanation for the other two units whose ages are even more loosely constrained. The origin of this fabric in these rocks is thus uncertain.

The later, “Acadian” influence on the rocks of the inlier is more pervasive and affects nearly all rocks exposed. Extremely massive and coarse-grained sedimentary rocks are weakly un-affected and many of the mafic intrusions show little evidence of foliation. This fabric is expressed as a slaty cleavage in the fine-grained rocks and either not present in massive coarse-grained rocks or as a spaced cleavage. Where observed in the previously foliated rocks, this later foliation is present as a spaced cleavage commonly with an associated crenulation of the

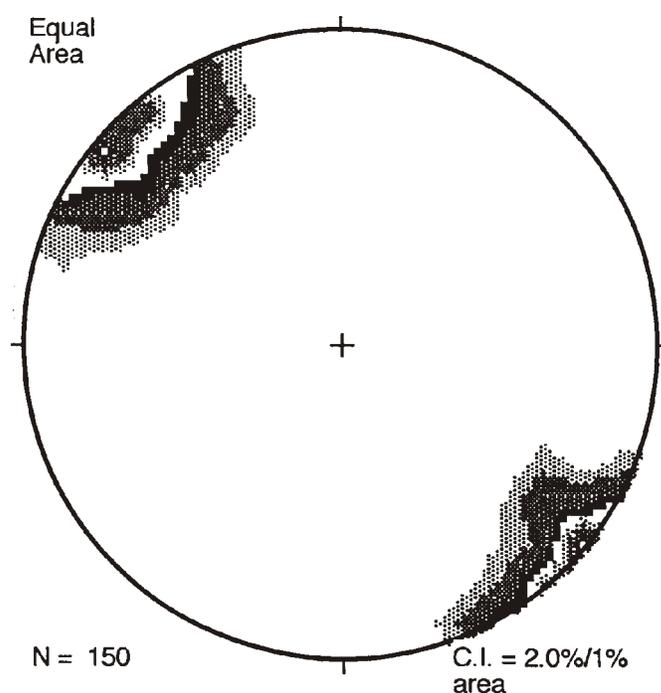


Figure 15. Poles to “Acadian” cleavage in the western end of the Grand Lake Seboeis inlier.

earlier fabric. The foliation dips steeply and strikes NE-SW (see Fig. 15).

Faults

Thus far in the area investigated, four faults have been identified. Also of note is that the southeastern boundary of this inlier is defined by the Beaver Brook fault as described by Hibbard (1991, 1992). The fault between the unnamed gray phyllite and the Millinocket Lake belt has been previously discussed. This fault crops out for about 30 m on the west side of the quarry exposure of the phyllite. It is inferred because of the extreme disruption in the phyllite unit, the pervasive veining in the nearby basalts, and an apparent metamorphic grade difference between the two units. Neither the fault nor the phyllite have been observed along strike or anywhere else in the inlier.

A northeast-trending fault of uncertain dip is inferred to separate the volcanic and volcanoclastic rocks of the Millinocket Lake belt from the Grand Lake Seboeis sedimentary rocks to the southeast on Big Beaver Pond. The island in the pond consists of predominantly highly disrupted and sheared(?) volcanoclastic rocks. The nature of the fault’s motion is uncertain, however the lithologic contrast across the inferred fault suggests south-side down. The rocks to the southeast are featureless dark gray slates and exhibit little sign of structural deformation other than a single cleavage. The full extent of this fault has not yet been investigated.

A third fault and perhaps a major fault in the area is inferred to run roughly lengthwise down the middle of Millinocket Lake. There are three lines of evidence suggesting its presence. The first has been mentioned, the extreme disruption of the felsite on the northern shores of Libby Island. Another part of the evidence is less direct, but it is interpreted that the unnamed lavender slate(?) of the southeastern shores of Little Millinocket Lake and farther to the southwest represents a continuation of this structure. Third, highly deformed volcanoclastic rocks and sedimentary rocks in the vicinity of Libby Camp on the northeastern shores of the lake have the sense of tectonite fabrics, deformed clasts in conglomerate that suggest movement has occurred in the area. Based on outcrop observation, the overall sense of shear indicated was left-lateral, however more detailed examination is necessary to completely and accurately characterize the fault.

The fourth northeast-trending fault studied appears to separate or lie close to the boundary between the Millinocket Lake belt volcanoclastic rocks and Grand Lake Seboeis group clastic sedimentary rocks on the southeastern side of Beaver Pond Ridge. Fine-grained silver phyllite is observed along the interpreted fault and is thought to be a fault-related alteration of volcanic conglomerate(?) observed adjacent to the fault. The conglomerate is heavily foliated and clasts are increasingly more difficult to discern as one approaches the fault. The phyllitic rock has a low angle dip and appears to have been crenulated and folded by Acadian deformation that overprints the low-angle layer-parallel fabric. The fault appears to pass into the Grand Lake Seboeis group farther to the southwest. No kinematic indi-

cators have been observed along the fault. More detailed examination of these structures is planned for the 1992 field season.

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